NASA SP-5079

CONSTRUCTING INEXPENSIVE AUTOMATIC PICTURE-TRANSMISSION GROUND STATIONS

A REPORT

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Foreword

Weather satellites, together with communications satellites, are among the products of space research of most practical benefit to mankind. The capability of satellites to observe conditions in the Earth's atmosphere rapidly and comprehensively was recognized early as a tool that would aid in global weather forecasting.

To obtain global weather data quickly at a central point for study, designers adopted data-storage readout procedures for the early weather satellites. Later, with the addition to some satellites of the continuous broadcasting feature of the Automatic Picture Transmission (APT) System, information could be transmitted immediately directly to local weather stations. APT enables remote sites to receive instant weather information.

When it was designed in 1960, APT used state-of-the-art components to meet its requirements. Some parts were expensive. The recent advent of less expensive, high-quality electronic components, together with the use of advanced electronic design experience, has made possible equipment which can easily be built in most parts of the world. This report is a guide to the construction of an economical, useful APT weather instrument for the direct reception of cloud-cover pictures from satellites.

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Summary

This report describes how one can procure or build the antenna, FM receiver, and other components for an Automatic Picture Transmission (APT) ground station. Detailed drawings and parts lists are included. Installation, alignment, and operation of the APT ground station are also described.

APT ground stations are inexpensive and reliable. They can be built from surplus parts for under $500 or procured for as low as $5000. With them, scientists, local weather stations, amateurs, and others can receive satellite-taken photographs of the Earth as APT-equipped satellites pass overhead.

It is currently planned that APT systems compatible with the ground station will be flown on Nimbus and ESSA satellites at least until 1972. It is probable that similar or advanced APT systems will be available after 1972, although these programs are still in a tentative planning stage.

CHAPTER 1

Introduction

The automatic picture-transmission (APT) system developed by the U. S. National Aeronautics and Space Administration (NASA) is a unique television system enabling a weather satellite to take cloudcover pictures over wide areas and transmit them to simple and inexpensive ground stations anywhere on earth.

The first APT-equipped satellite was TIROS VIII, an experimental version, launched December 21, 1963. Two APT-equipped experimental Nimbus satellites, launched August 28, 1964 and May 15, 1966, successfully demonstrated the APT system by transmitting thousands of APT pictures directly to receiving stations all over the world. The later TIROS operational satellites, named ESSA* when they achieve orbit, will provide continuous APT coverage on a regular operational basis. These satellites are built and launched under the technical direction of the NASA Goddard Space Flight Center and are operated by the U. S. Environmental Science Services Administration (ESSA).

By using APT equipment, a ground station can receive photographs and other pictorial information transmitted by APT-equipped satellites passing overhead taking photographs and infrared pictures of the clouds and terrain in the vicinity of the ground station. In addition, there is an experimental program for the relay of pictorial information to APT ground stations through an ATS satellite as shown in Fig. 1. This experiment may lead to additional uses for the APT ground stations in the future (Ref. 1).

APT ground station equipment is inexpensive and reliable. It can be built using surplus equipment for a few hundred dollars or purchased ready-made for around $5000. Simplicity, direct reception and "instant" pictures make the APT system particularly useful to meteorologists, weather services, commercial organizations, government agencies, and educational institutions. For instance meteorologists at weather offices and TV stations can receive daily pictorial displays of the local cloudcover in less time than it would take to dial a telephone and get a complete weather forecast. A weather picture from a typical APT-equipped satellite is complete within about 200 seconds. Pictures of cloud patterns signifying weather conditions are thus immediately observable. Utility companies can keep an eye on weather changes affecting power and water consumption. Individual

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*ESSA = Environmental Survey Satellite.

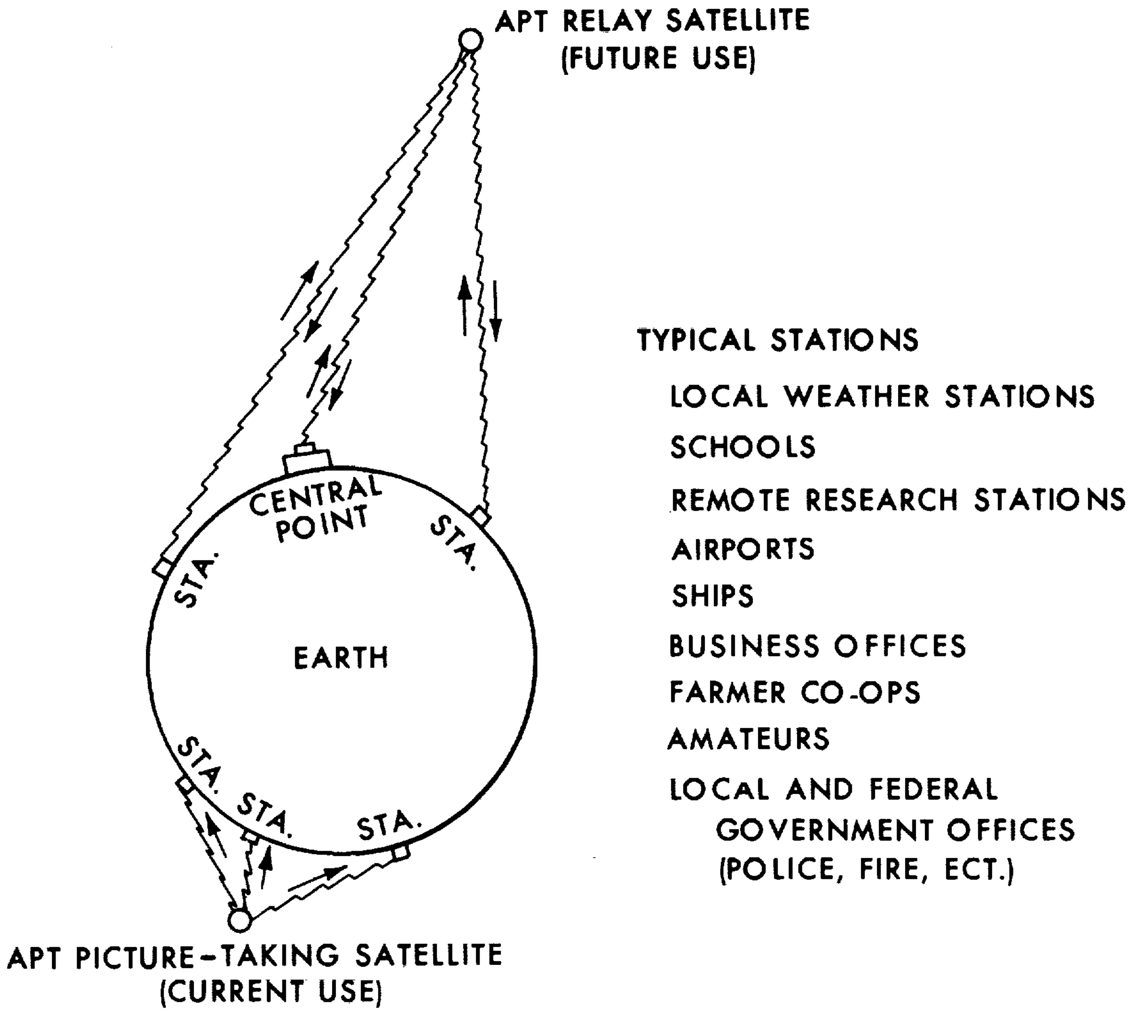

Figure 1.—APT ground equipment used with picture-taking satellites and picture-relay satellites.

weather services can provide detailed data on conditions hundreds of miles around their station. The universally available cloudcover pictures can also provide weather data to encourage accurate meteorological interpretation to localities not normally served by weather bureaus. At present, weather satellites in the Nimbus and ESSA series include APT equipment in their payloads. APT ground stations have already sprung up all over the world, and thousands of cloudcover pictures are recorded every week.

CHAPTER 2

How The APT System Works

THE APT-EQUIPPED SATELLITE

The operation of the APT system, now carried by ESSA and Nimbus satellites, can be compared to regular television operation. When these weather satellites cross the day portion of the globe in their near-polar orbits, their special television cameras (vidicons) are pointed at the Earth below. The system is completely automatic and requires no ground commands for operation. In the daylight portion of the revolution, an internal sequence timer exposes the vidicon and begins the read-out process a few seconds later. This process is accomplished by scanning the stored picture from the face of the vidicon. This picture is scanned 800 times, resulting in 800 lines of picture information (ref. 2). The density of electrons stored on the face of the picture, which correspond to the shades of grey in the picture, is detected by the electron beam in the vidicon. The resulting current beam is used to amplitude-modulate a 2400-Hz subcarrier, which is sent to the APT transmitter for relay to waiting ground stations (fig. 2).

An APT satellite will pass within range of any ground station two or three times during daytime. A receiving station can receive weather pictures taken over regions up to 2000 miles distant. For example, the station in Greenbelt, Maryland, can receive pictures taken from Central America to Greenland. Local weather pictures are of primary interest, however, and these can be obtained from ESSA and Nimbus satellites, which will pass almost directly overhead once daily. Each picture covers an area measuring approximately 1200 miles (1920 km) square (Nimbus) or 1700 miles (2730 km) square (ESSA); a pair of successive pictures will overlap about 30 percent on the ESSA satellite and 50 percent on Nimbus II (figs. 3 and 4).

The satellite radiates approximately 5 watts of power. The power received on the ground within the area of reception (fig. 4) is sufficient for clear pictures if the station has the proper receiving equipment. (See figs. 5 and 6 for an idea of the distance useful pictures may be transmitted.) The area of reception increases proportionately with increasing altitude of the satellite (e.g., 1400 km for ESSA IV, 1200 km for Nimbus II). Each station should be able to acquire a satellite at about 5 degrees in elevation, which represents an approximate line-of-sight distance of 3500 miles.

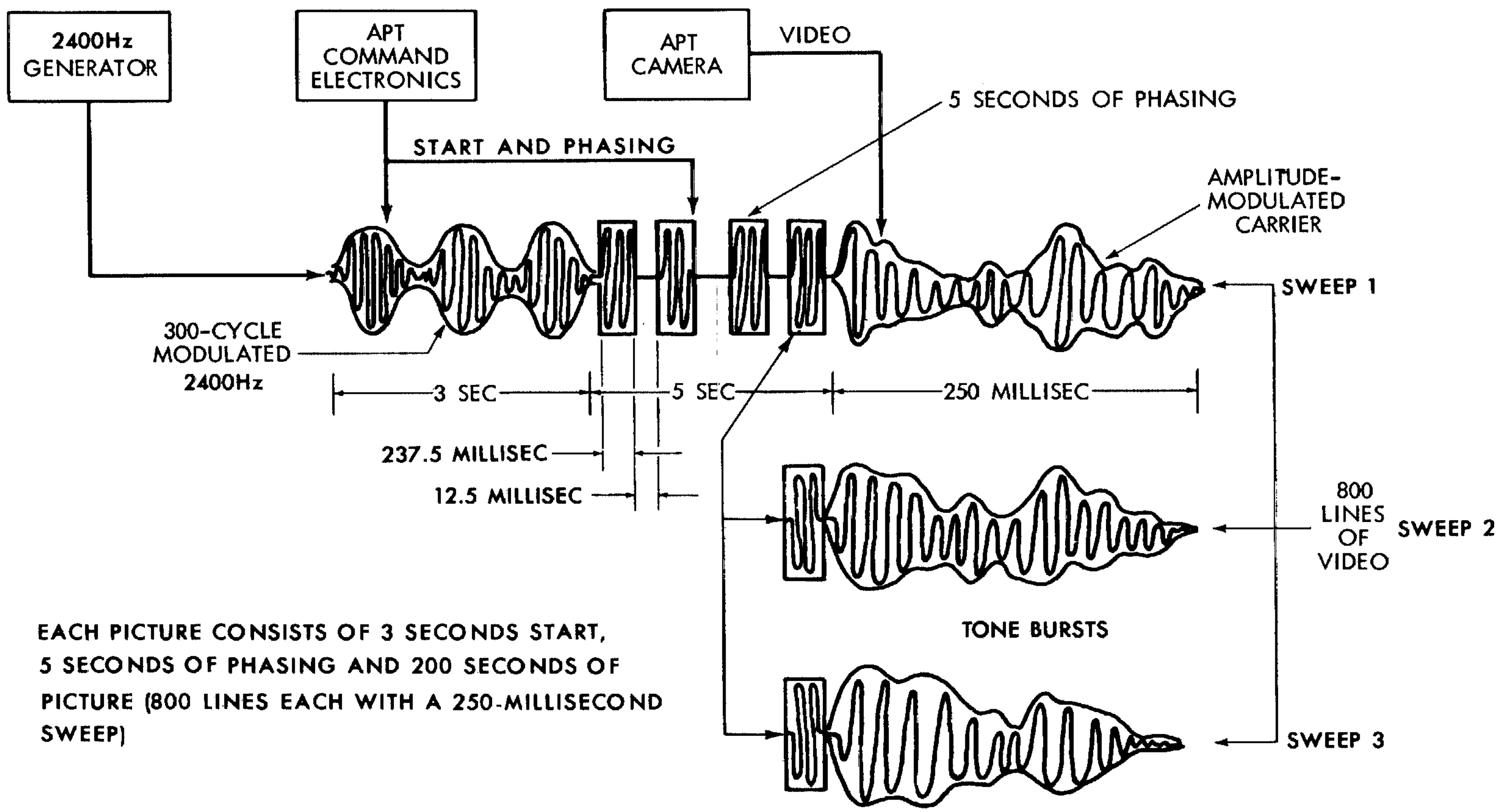

Figure 2.—Signal structure from an APT-equipped satellite.

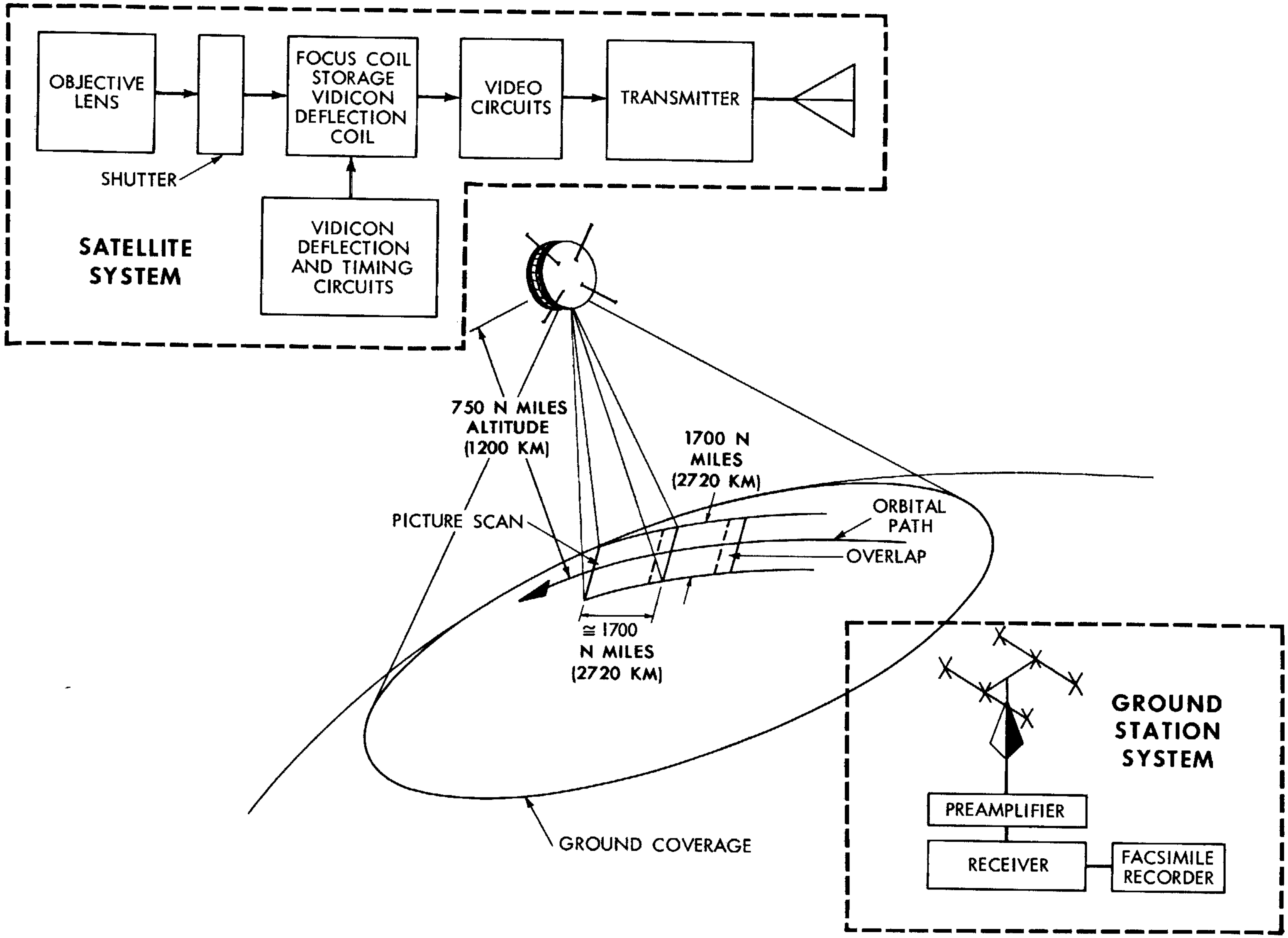

Figure 3.—Automatic Picture Transmission (APT) system.

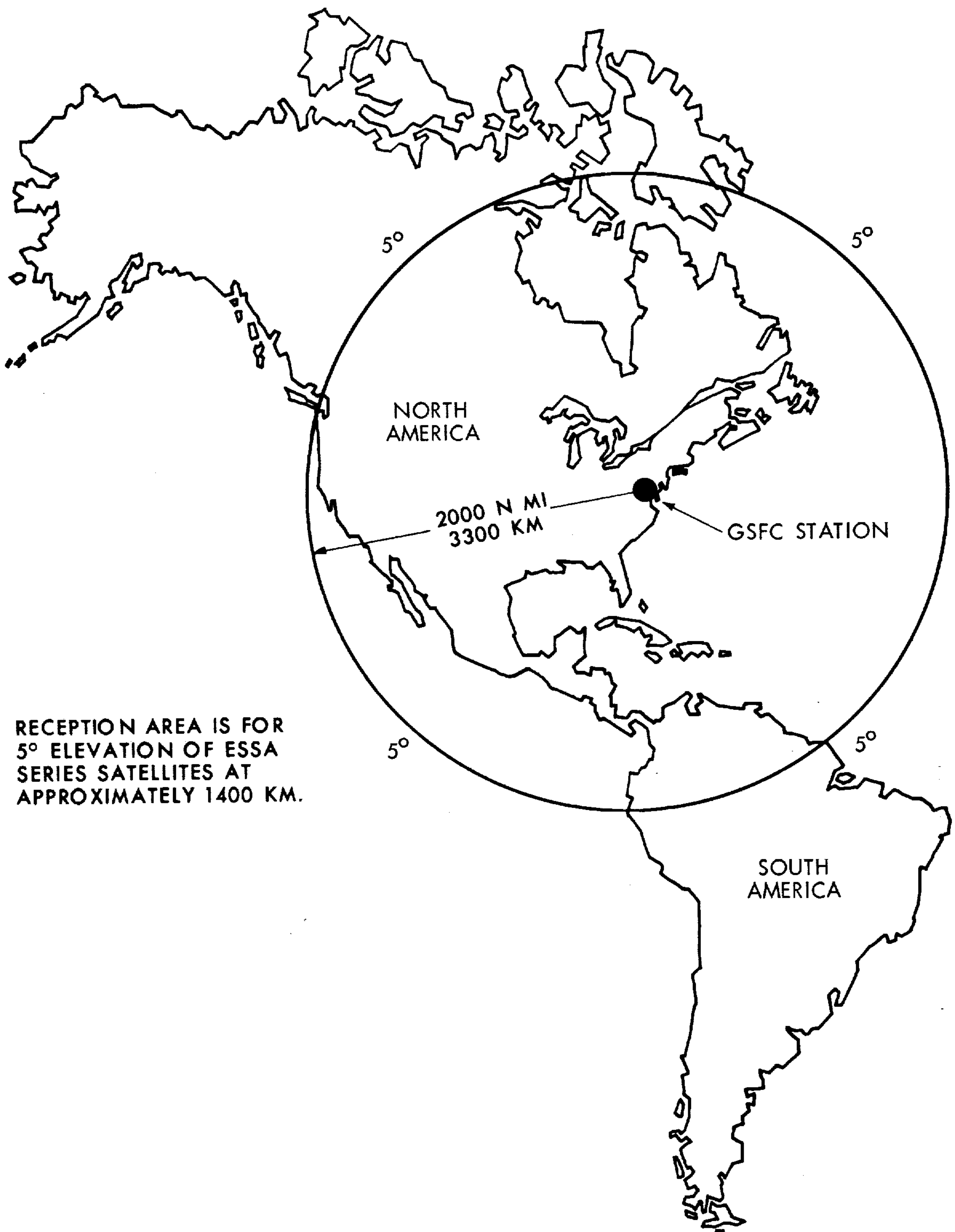

Figure 4.—Area of possible reception.

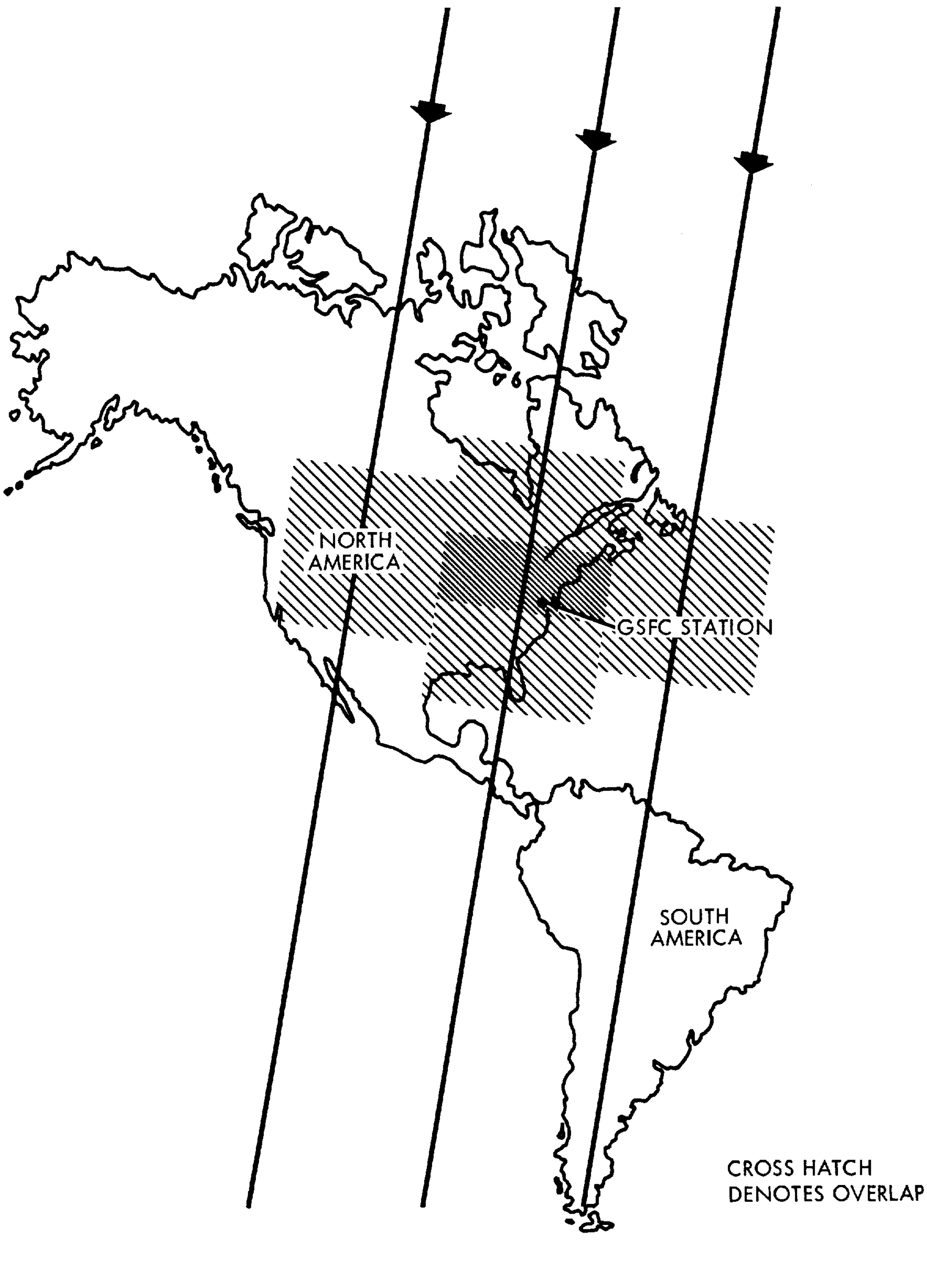

Figure 5.—Area of local reception.

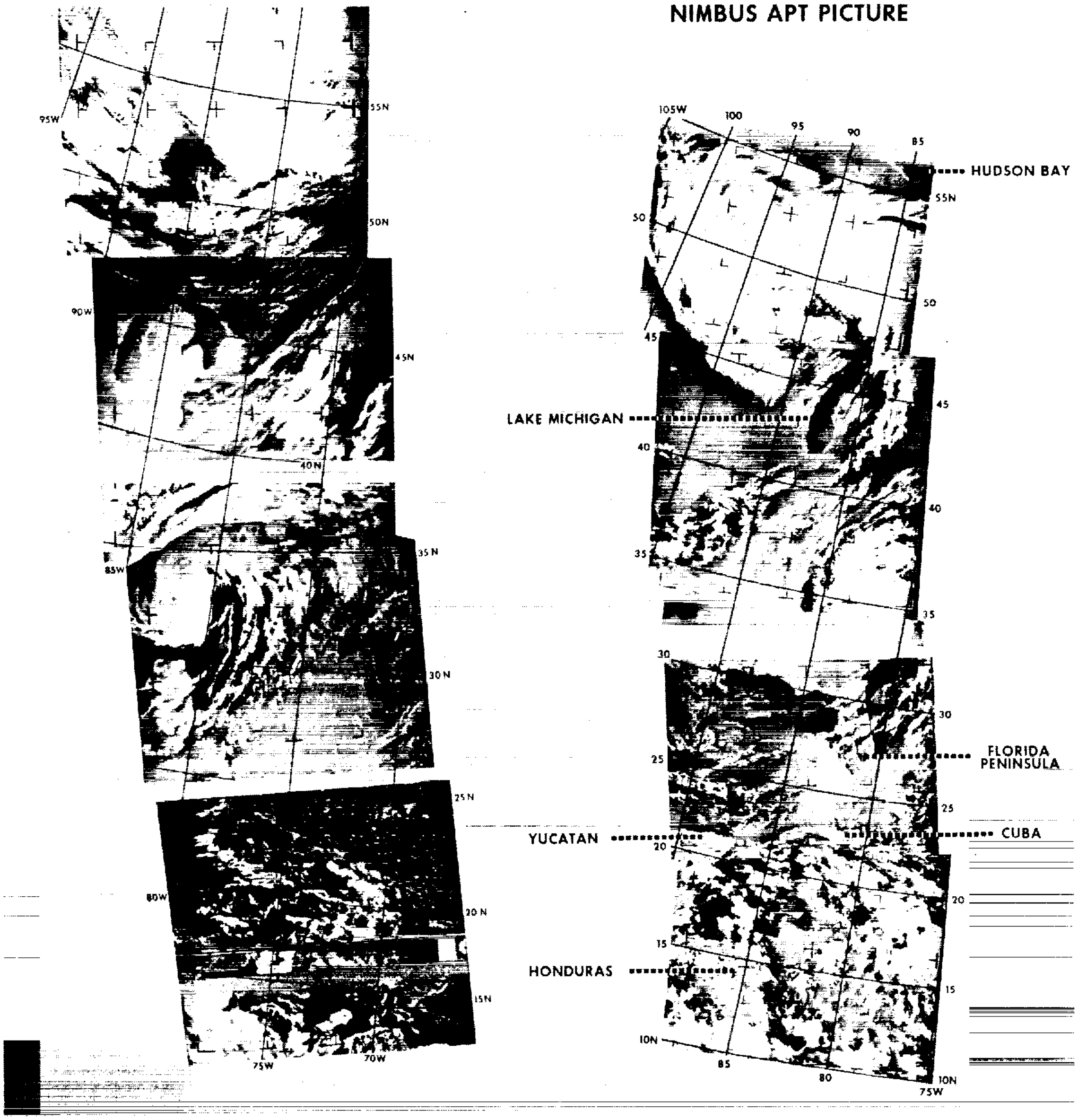

Figure 6.—Nimbus APT pictures received at Goddard Space Flight Center.

THE APT GROUND STATION

Once the satellite is in range, the video signal can be heard in the receiver output. The first picture transmitted is of little value because:

- It is usually "noisy."
- It is not of the local area.
- The station did not receive the start and phase portion of the transmission.

This is a good time to tune the receiver and make a last-minute check of the station to verify its readiness to receive pictures. The antenna operator tracks the satellite with the orbital prediction data he has calculated using the information he has received from the National Environmental Satellite Center by mail or teletype.* (The APT User's Guide, ref. 3, is a requirement for all APT stations and explains satellite tracking in detail.) By the time the first local picture is transmitted, the station will receive a good clear signal, indicated by a "buzzing" sound that interrupts the normal "beep" tone. This is the 300-cycle start, followed by the phasing signal (refer to fig. 2). Together these take 8 seconds. The 800 lines of picture information that immediately follow take 200 seconds to be transmitted and received. ESSA spacecraft, with their rolling-wheel method of stabilization, revolve at 10 rpm and will not take another picture until they are again in proper position. This takes about 140 seconds, during which time the spacecraft transmits no picture information, only a steady 2400-Hz tone. After the satellite senses that it is in position, another picture is taken and transmitted.

The Nimbus spacecraft is different from the ESSA spacecraft because it is an Earth-oriented satellite always pointing toward the Earth; there is no time lapse between the end of one picture and the start of another.

About twenty minutes are required to track an overhead pass from horizon to horizon. Each satellite will yield up to five good pictures per pass.

*For all material and prediction data needed to calculate orbital information, write to: APT Coordinator, United States Department of Commerce, Environmental Science Services Administration, National Environmental Satellite Center, Washington, D. C. 20233. USA.

CHAPTER 3

Building The APT Ground Station

Figure 7 is a simplified block diagram of the APT ground station described in this report. During construction, every precaution should be taken to prevent errors in wiring. Each component should be checked before it is used. Care in the early stages of construction can save much time and money later.

The component and circuit descriptions which follow assume only that the builder has a good background in electronics and adequate test equipment.

THE ANTENNA

DESCRIPTION

The antenna, apart from its pedestal, is a critical component of the system. It can easily be built to the following specifications or may be purchased for about $250.00 (at U. S. prices).

The antennas are pictured in figs. 8 and 9.* Whether purchased or handmade, the antenna must have the following characteristics:

- Desirable antenna gain: at least 11 db for elevations from 5 to 90 to 5 degrees.
- Acceptable antenna gain: at least 9 db for elevations from 15 to 90 to 15 degrees. Nine db will insure local coverage.
- Beamwidth: 45 ± 5 degrees. This is wide enough to provide easy tracking, yet narrow enough to yield sufficient gain.
- Frequency: 130 to 140 MHz.
- Polarization: right-hand circular.

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*The antennas pictured are made by TACO, although Scientific Atlanta, Hi Gain, Textran, and other antenna manufacturers build equally satisfactory equipment. For general construction techniques, see: Radio Amateurs Handbook. American Radio Relay League, 225 Main St., Newington, Connecticut, 06111. Latest edition: $4.00; and VHF Handbook. Radio Publications, Danbury Road, Wilton, Connecticut, 06897, latest edition: $2.95.

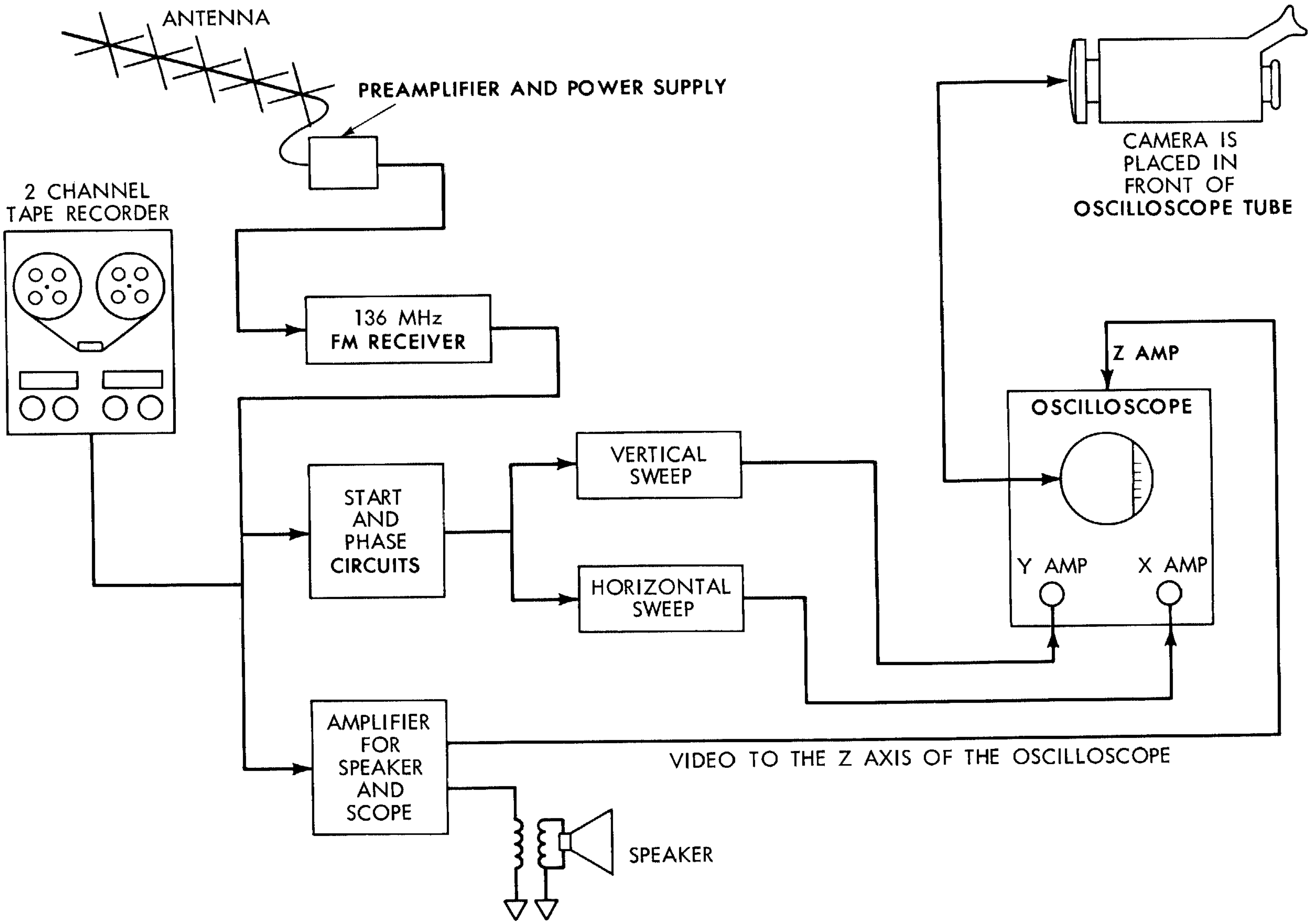


Figure 7.—Simplified block diagram of the low-cost APT station.

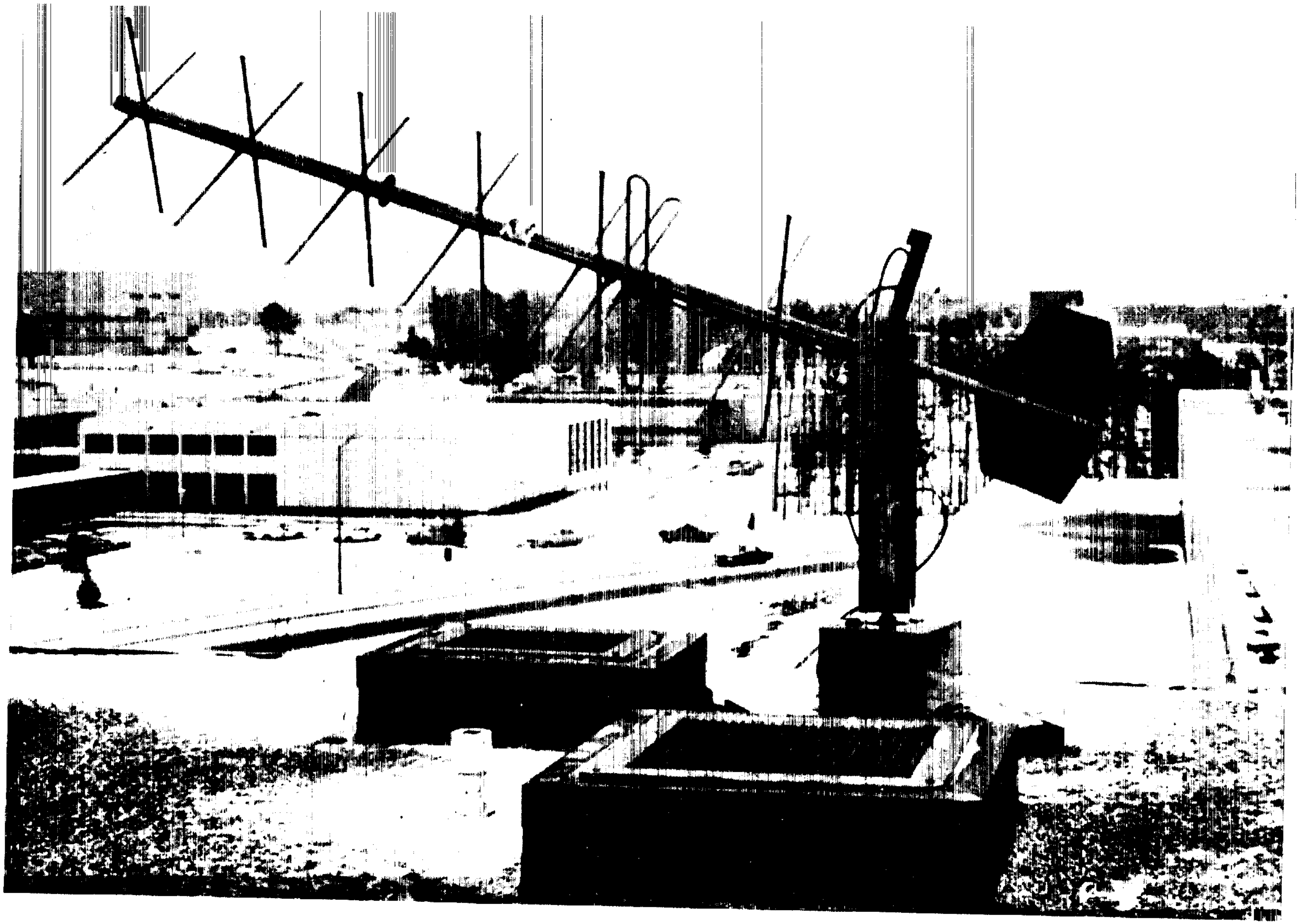


Figure 8.—Dual-axis, single-boom crossed Yagi array.

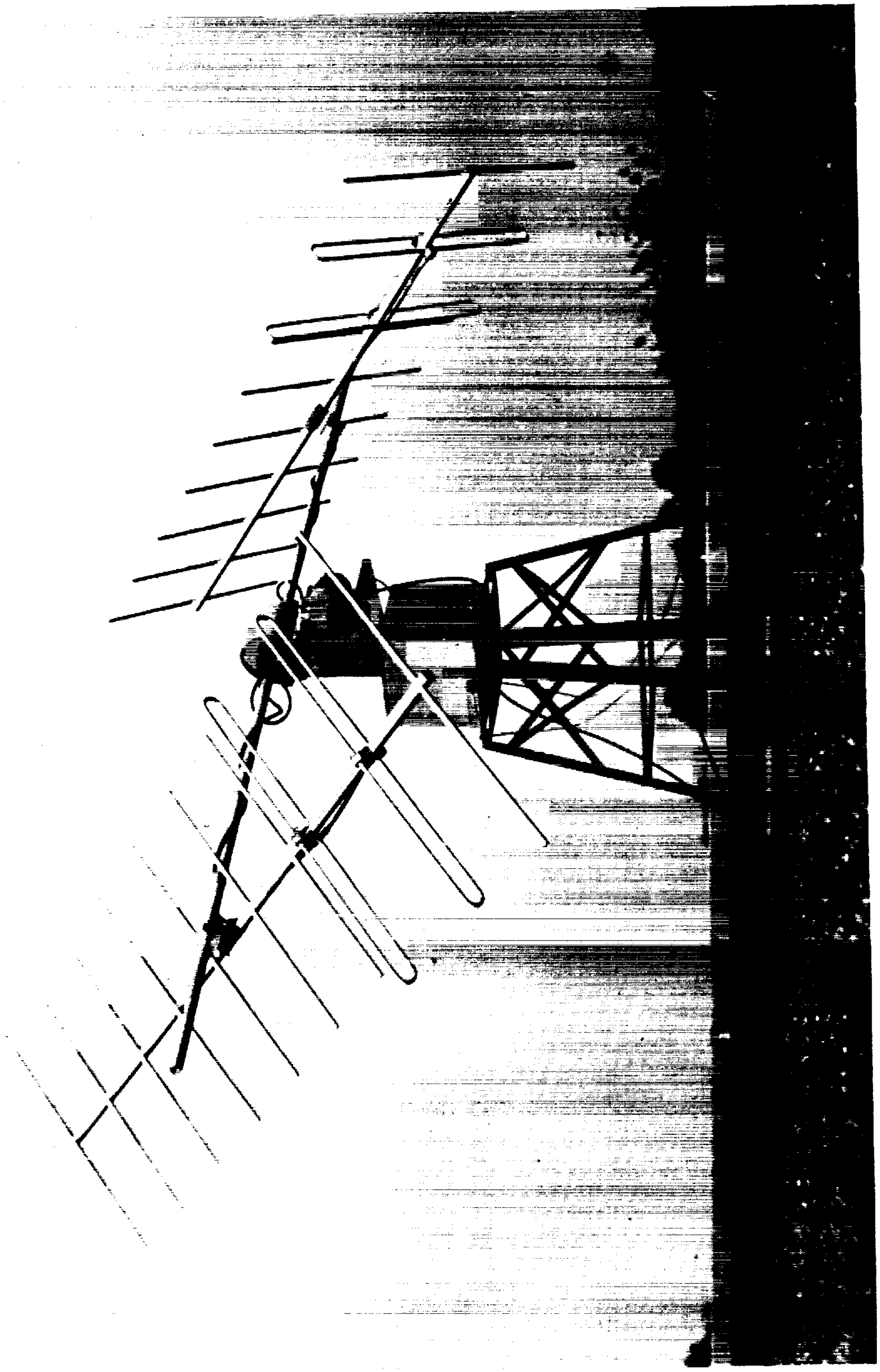


Figure 9.—Dual-axis, double-boom crossed Yagi array.

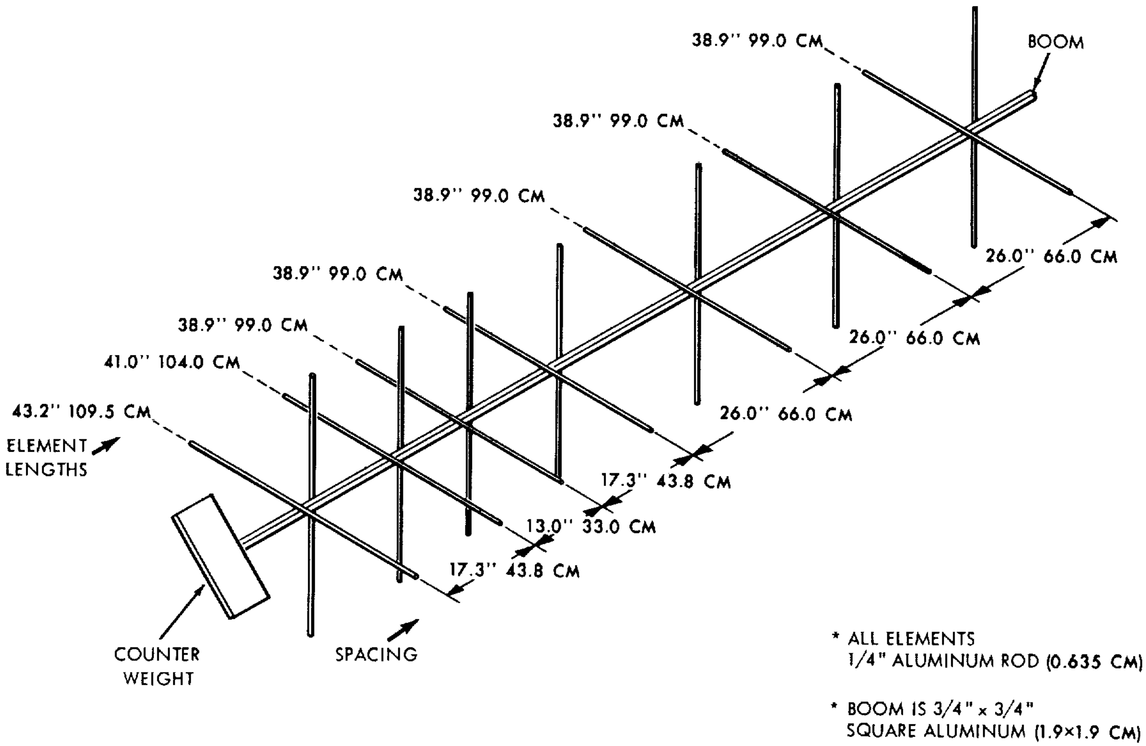


Figure 10. —Antenna element-spacing diagram.

Figure 10 gives element lengths and spacings for a single-boom, crossed-Yagi array. A matching device is required to match the impedance of the array to that of the coaxial transmission line. A gamma match is suggested.

In fig. 11 the connections of the arrays, phasing lines, coaxial switches, and the transmission line are shown. The lengths of cable are joined with coaxial TEE fittings. Switches permit selection of various antenna polarizations to improve the signal.

An overall view of the antenna array is shown in fig. 12. A rectangular boom is preferable to a round one because it is easier to mount the elements on it. Rectangular tubing, however, is more expensive and harder to obtain. If the boom is heavy enough, strengthening guy wires will not be needed. Guy wires, if used, should be nonmetallic and provided with a means for keeping them taut.

ANTENNA POSITIONING DEVICE

The antenna must be mounted so that it can be positioned in azimuth and elevation. Motors for this purpose can be purchased from any of several manufacturers.* The motors should be procured with a control box which can be used in controlling them from the stations.

*A suitable type is the Cornell-Dubilier Electronics, Type HAM-M rotator, which sells for $130.00 each.

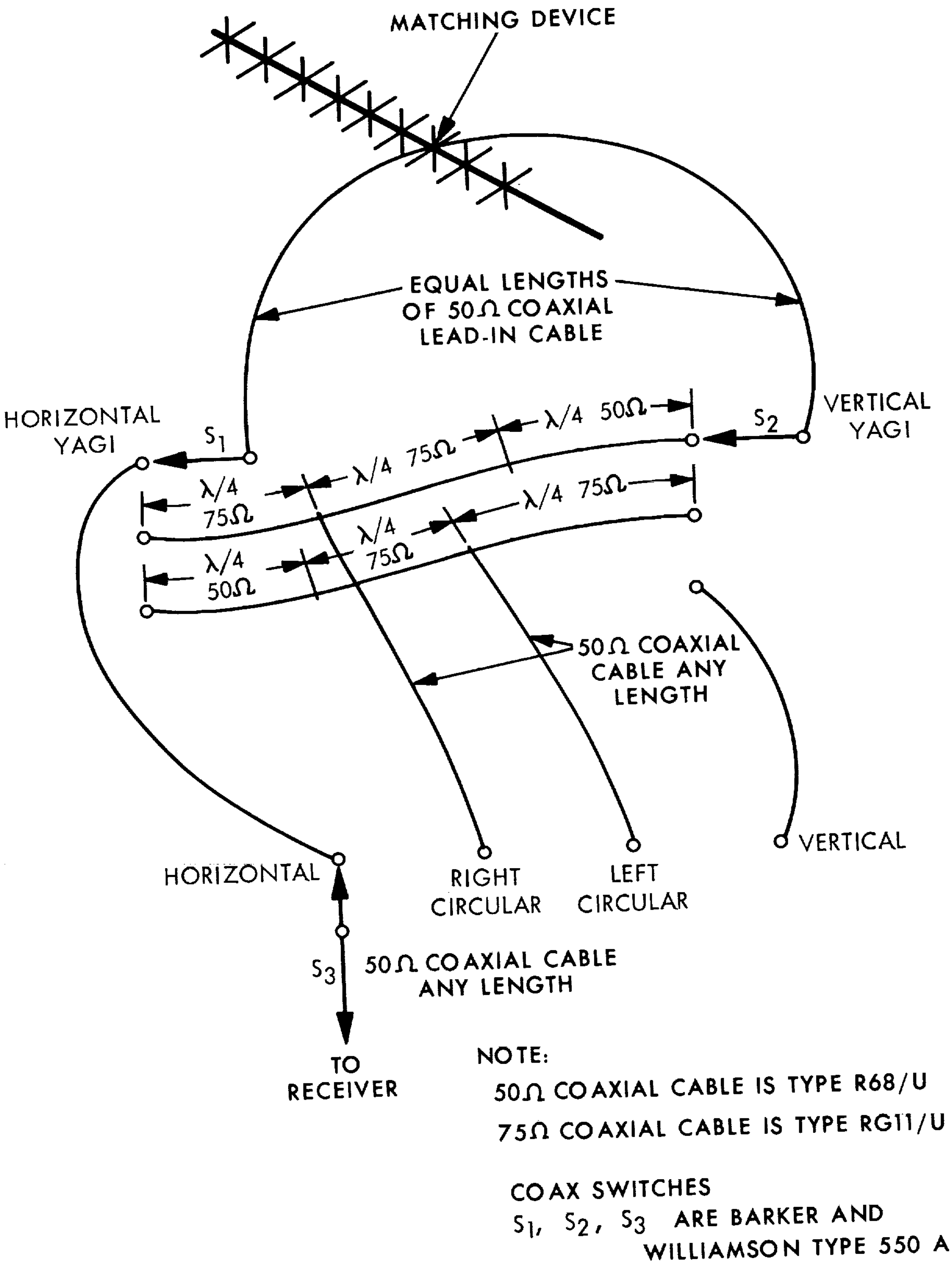


Figure 11.—Antenna-phasing diagram.

The motor shafts must be drilled and pinned with the gears. Select large "cast" gears for strength.* They must be at least 1-inch thick and of sufficient radius to give a 2-to-1 speed reduction. This will yield the proper speed and torque needed to move an antenna of the size mentioned. Refer to figs. 13 and 14 for a mechanical guide for the pedestal and motor mounting.

After the antenna is assembled and working properly, it must be oriented. Since the satellites are not in true polar orbits, the pedestal must be positioned so that it does not hit the azimuth stops during tracking (fig. 15). Set the antenna so that it will rotate from 350 degrees to 170 degrees with 0 degrees at TRUE NORTH (fig. 16). To rotate the antenna from 170 degrees through 350 degrees, the elevation rotator must be run all the way to the other side, with the antenna placed in the western sector. The antenna will track the satellite from horizon to horizon even when the satellite pass is at maximum elevation angle.

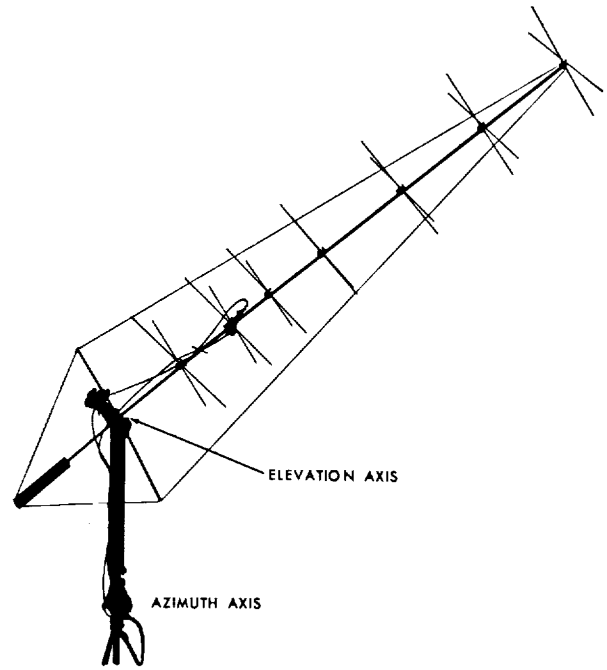


Figure 12.—Assembled Yagi boom support.

Bolt the antenna pedestal to a solid, level surface. This will help damp any oscillation and prevent the pedestal from blowing over in a storm. To bolt the base, pour a solid concrete foundation anchoring large bolts in the concrete before it has hardened. Fasten the antenna base to these bolts after the concrete dries. The antenna may be placed on a roof or tower, if the structure can support the weight (typical weight: 500 pounds).

The position control boxes are usually packed with the motors. Refer to the manufacturer's manual to calibrate the antenna position so that it reads the same as the meter indication. The scales must be removed and scribed, as shown in fig. 17. This may require the services of a draftsman, since these scales are an important part of the console.

ANTENNA PREAMPLIFIERS

The antenna's direct signal is too weak for reception. This condition becomes more severe as the distance is increased between the antenna and the receiver. The signal level must be boosted by a preamplifier located on the antenna pedestal. Of

*Those made by Boston, American Gear, or equivalent manufacturers will be satisfactory.

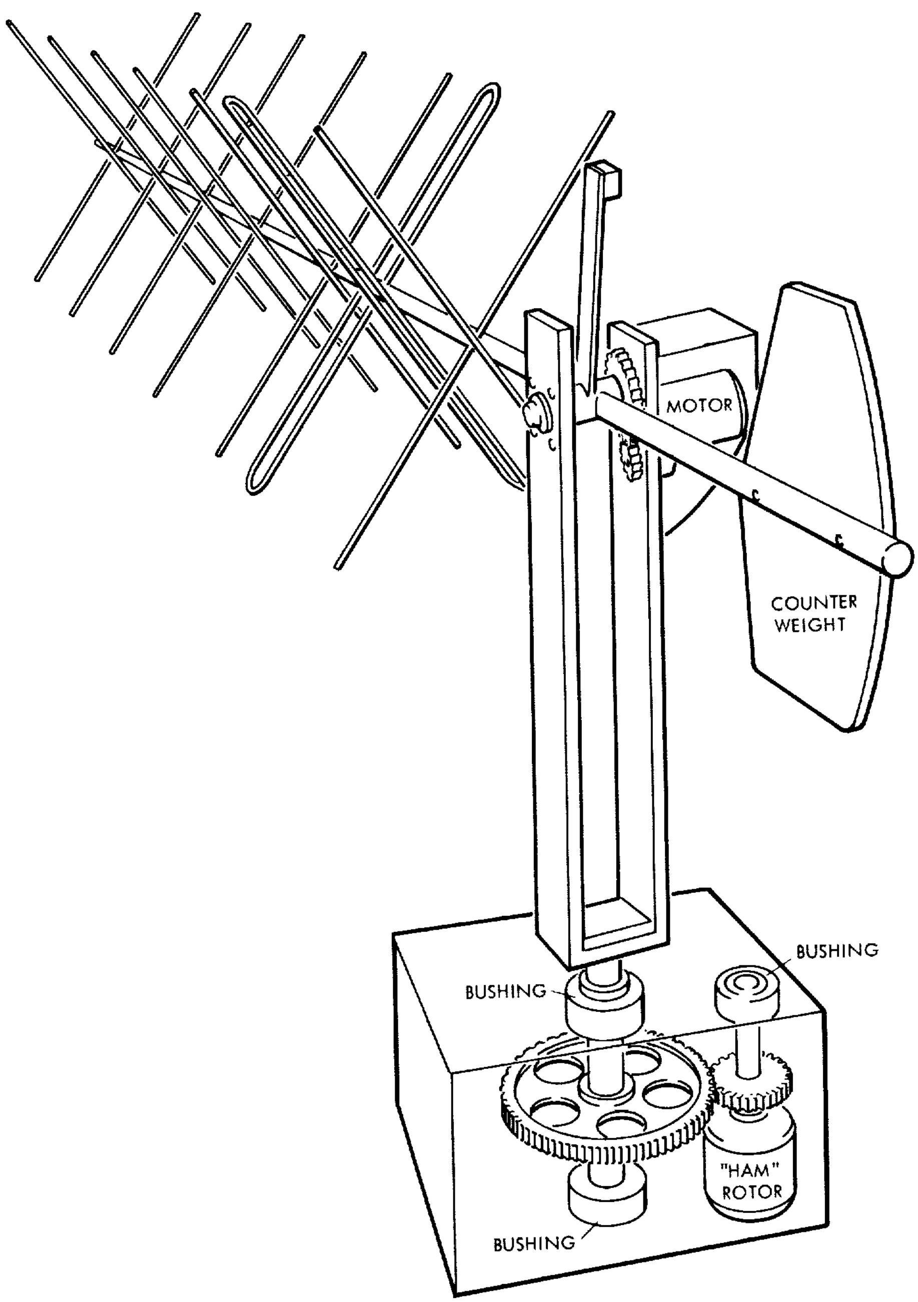


Figure 13.—Mechanical assembly of antenna pedestal.

the two versions of the preamplifier discussed here, version 1 is the easiest to build and can be used with any type of receiver. Version 2 can only be used with the receiver described in this document because it receives power from that receiver.

Figure 18 shows the schematic and coil construction data for preamplifier version 1. When this design is used, it is recommended that two preamplifiers be fabricated and placed in series to improve the signal level. The two units may be

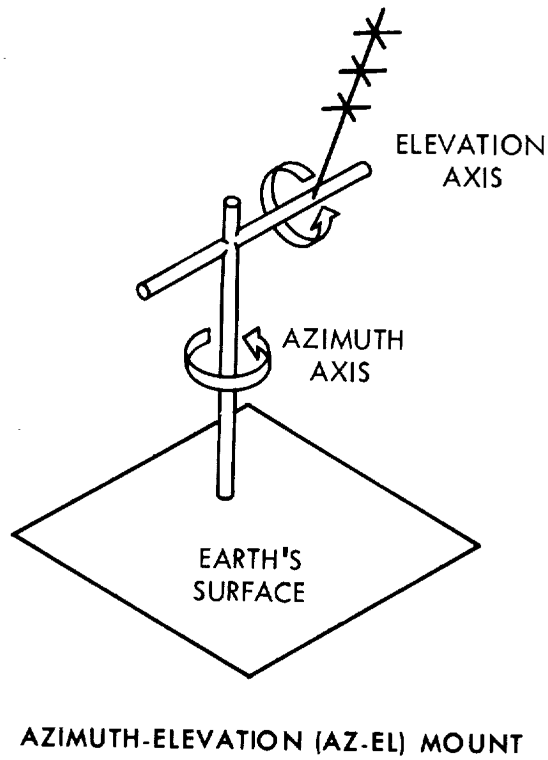


Figure 14.—Simplified antenna positioning.

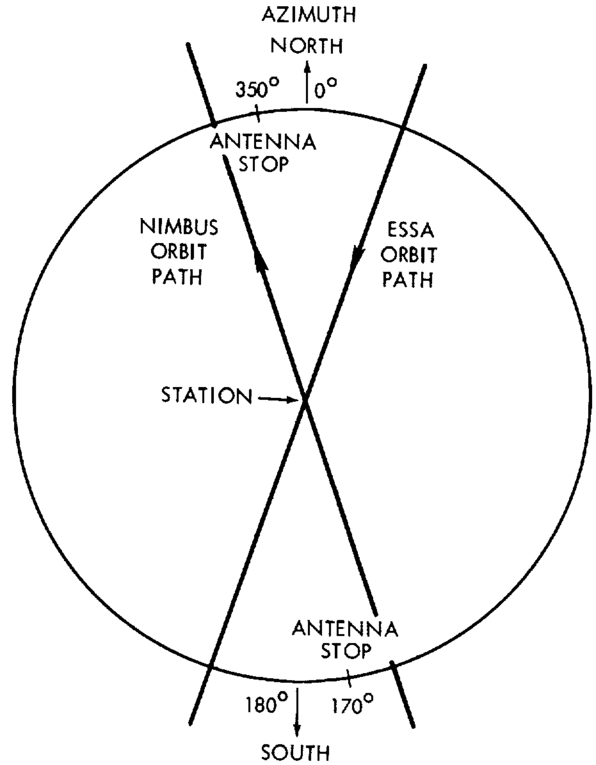


Figure 15.—Antenna orientation.

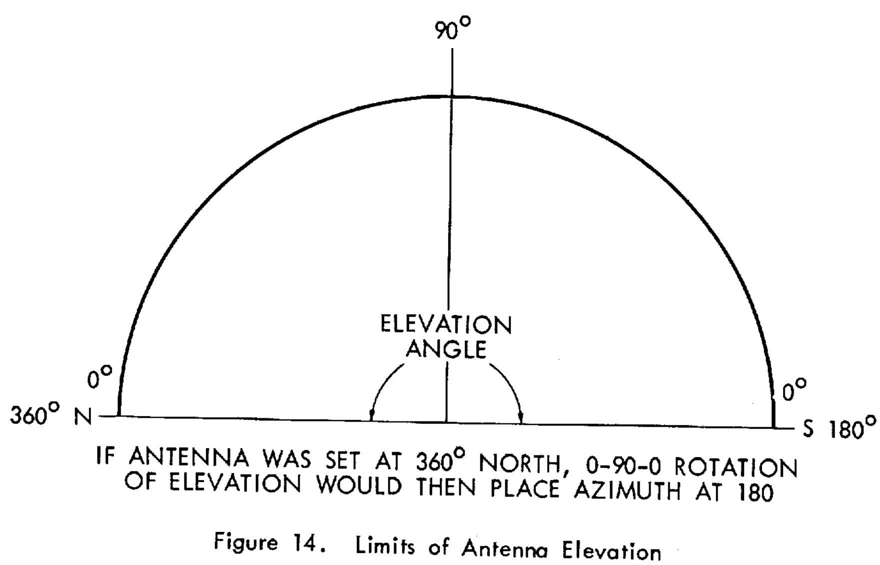
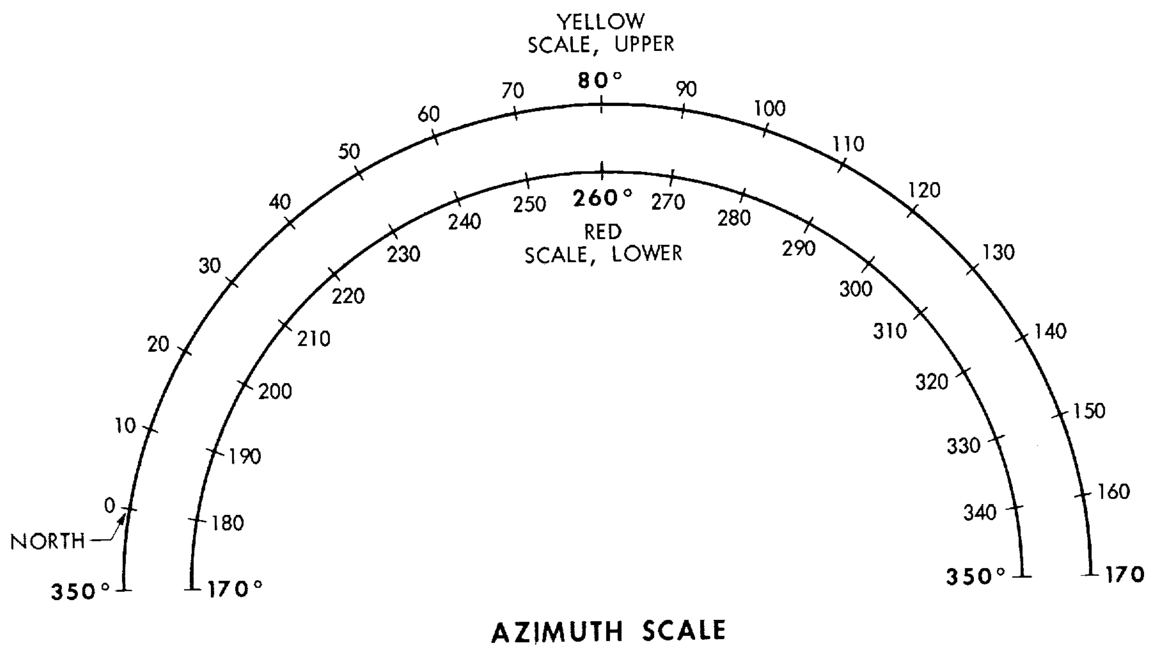


Figure 16.—Limits of antenna orientation.



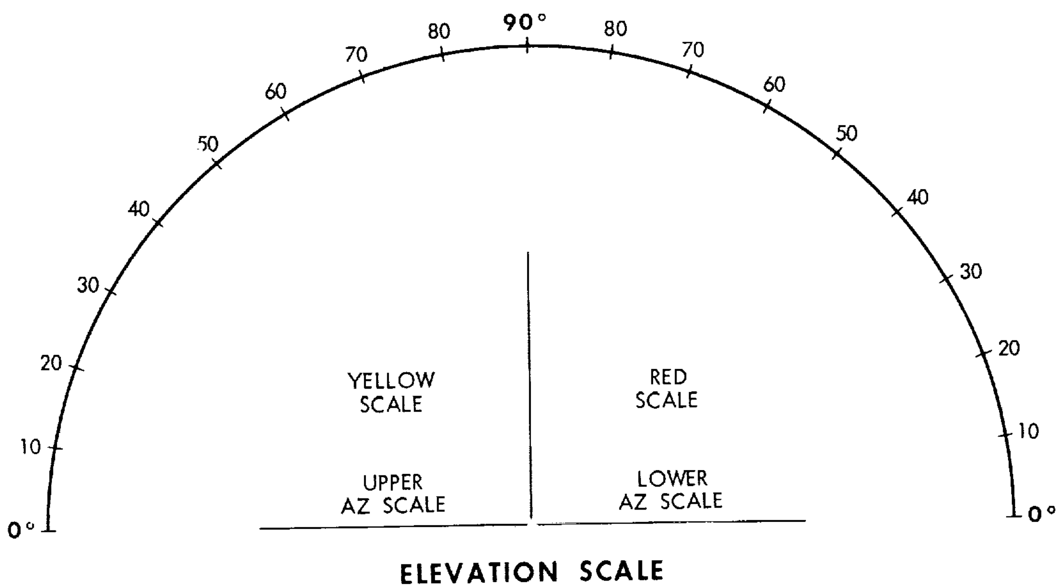
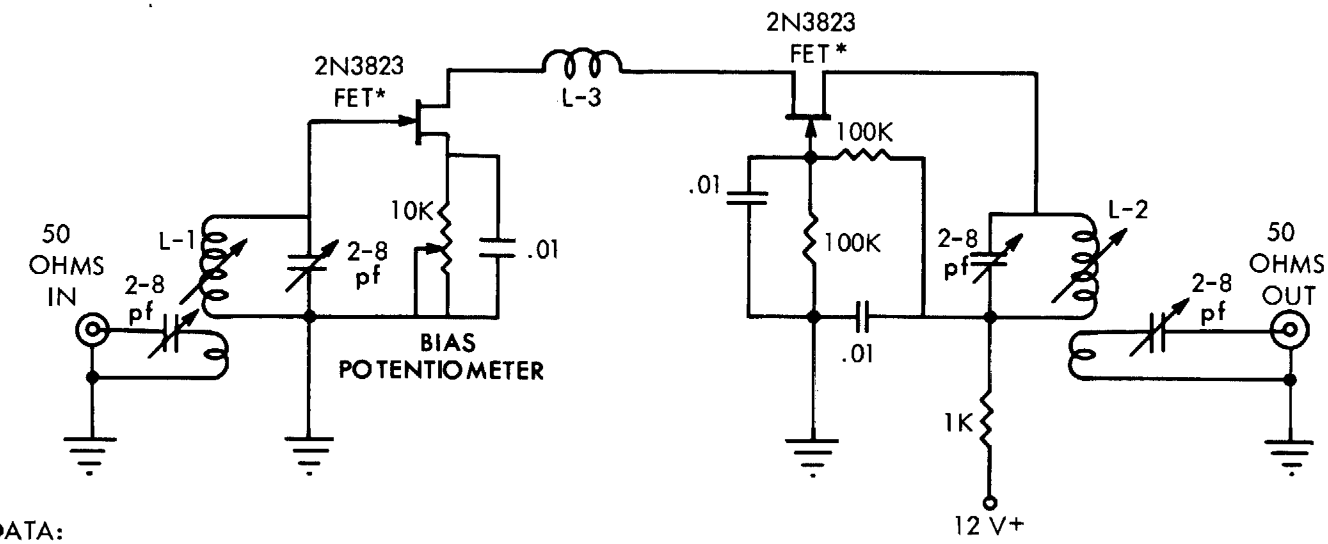


Figure 17.—Scales for recalibration of antenna-control boxes.



COIL DATA:
L-1; PRIMARY, TWO TURNS #22 PLASTIC INSULATED WIRE, CLOSE WOUND OVER THE COLD END OF THE SECONDARY.
SECONDARY, SIX TURNS #22 WIRE SPACED TO FILL FORM.

L-2; PRIMARY, SIX TURNS #22 WIRE SPACED TO FILL FORM.
SECONDARY, ONE TURN #22 PLASTIC INSULATED WIRE, CLOSE WOUND OVER THE COLD END OF THE SECONDARY.

USE CAMBION COIL FORM, PART #1536-4-2.

L-3; THIRTEEN TURNS #26 ENAMEL COATED WIRE, CLOSE WOUND ON 100K OHM 1/2W. RESISTOR AS CORE.

*FIELD - EFFECT TRANSISTOR (TEXAS INSTRUMENTS).

CAPACITOR VALUES IN MICROFARADS UNLESS OTHERWISE SPECIFIED.

Figure 18.—Antenna preamplifier, version 1, schematic.

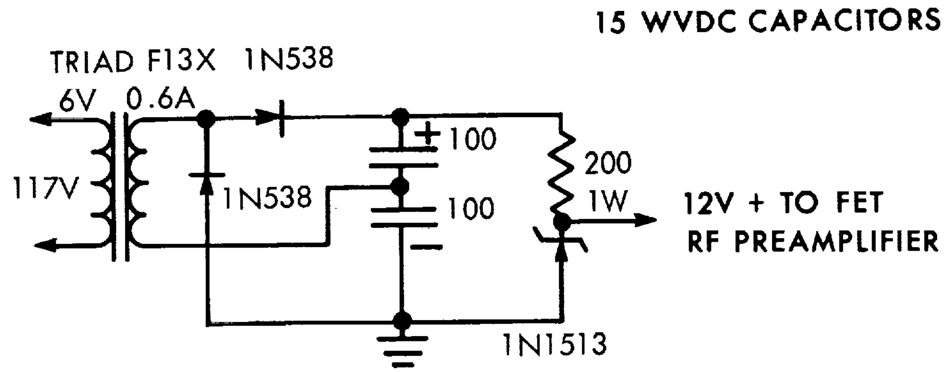


Figure 19.—Antenna preamplifier, version 1, power supply schematic.

placed in a single box of rigid aluminum construction, and completely weatherproof. Power can be fed in through an epoxy-sealed hole. Type-N coaxial connectors are used for input and output.

The number of turns in coil L3 does not appear to be critical. It can be adjusted at 136 MHz for the best noise figure. In order to keep distributed capacity to a minimum, the transistors were wired into the circuit and soldered directly to the leads. Leads should be as short as possible. All sensitive components must be protected from heat by placing a metal clamp between the soldering connection and the component body while heat is applied.

Tuning is not critical. A 136-MHz weak signal should be induced in the receiving antenna during all tuning adjustments. The bandwidth will be several MHz wide. Tuning can be accomplished with a noise generator.* If transmission line lengths are changed, amplifier circuits will probably need retuning.

The 2.8-pf capacitors used are the miniature type, about 3/8 inch (0.95 cm) in diameter. These capacitors should be soldered directly to the coil lugs. The adjustable capacitors across the input and output tank circuits are best set to near-resonance with the coil slug at its mid position. Fine tuning can be done from the top of the chassis.

Proper setting of the bias potentiometer is important because it affects both noise figure and gain. At zero bias, the circuit gain is at maximum and the amplifier is noisy. As the bias is increased, the noise output decreases exponentially. The bias control is properly set when both the gain and the noise decrease slowly. An exact value of bias cannot be given, because it varies with transistor characteristics.

Figure 19 shows a suitable power supply for preamplifier version 1.

Figures 20, 21, 22, 23, and 24 show the schematic and construction details for preamplifier version 2. This preamplifier receives its dc operating voltage

*If this equipment is not available, refer to: Radio Amateur's Handbook, ibid, or the VHF Handbook, ibid.

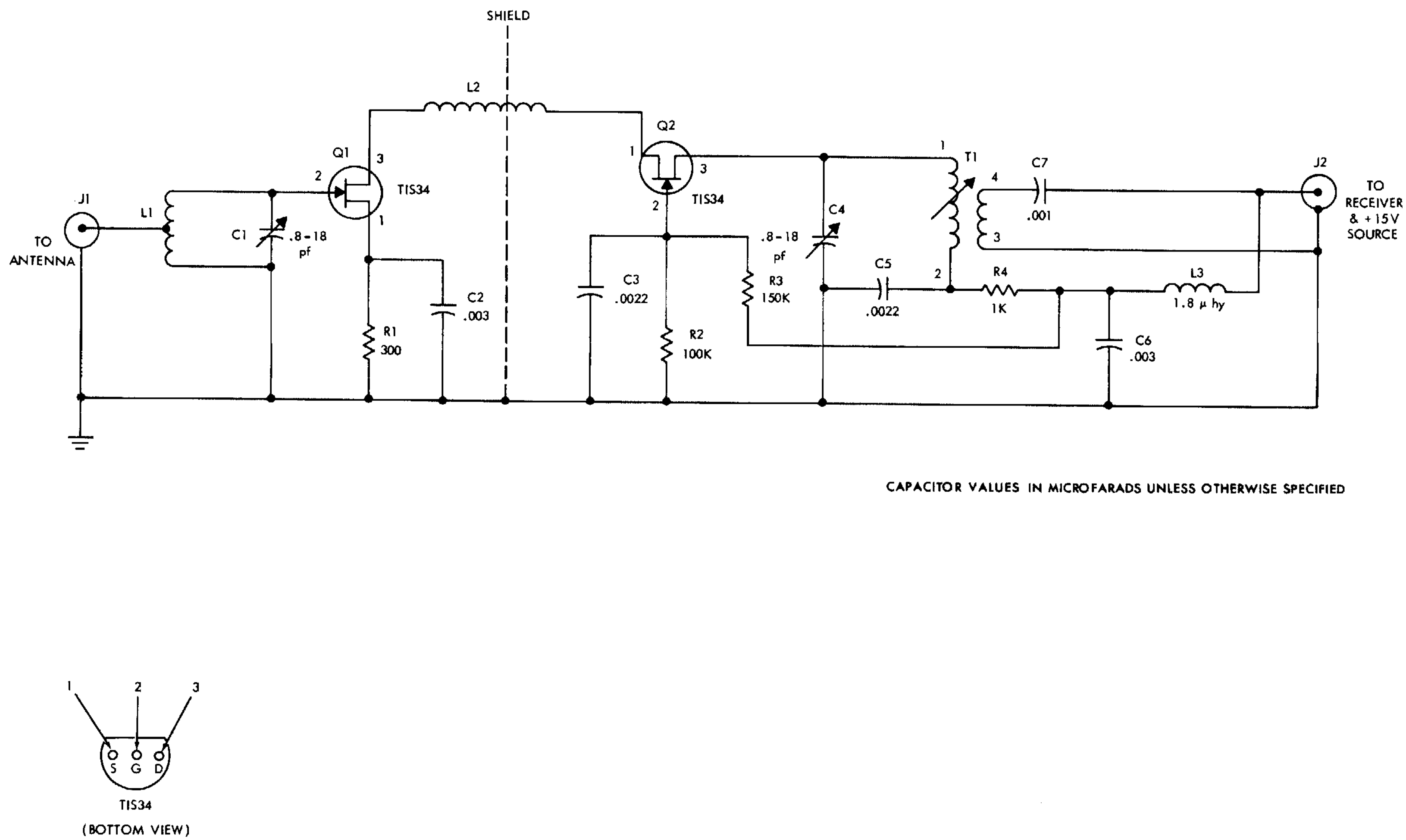
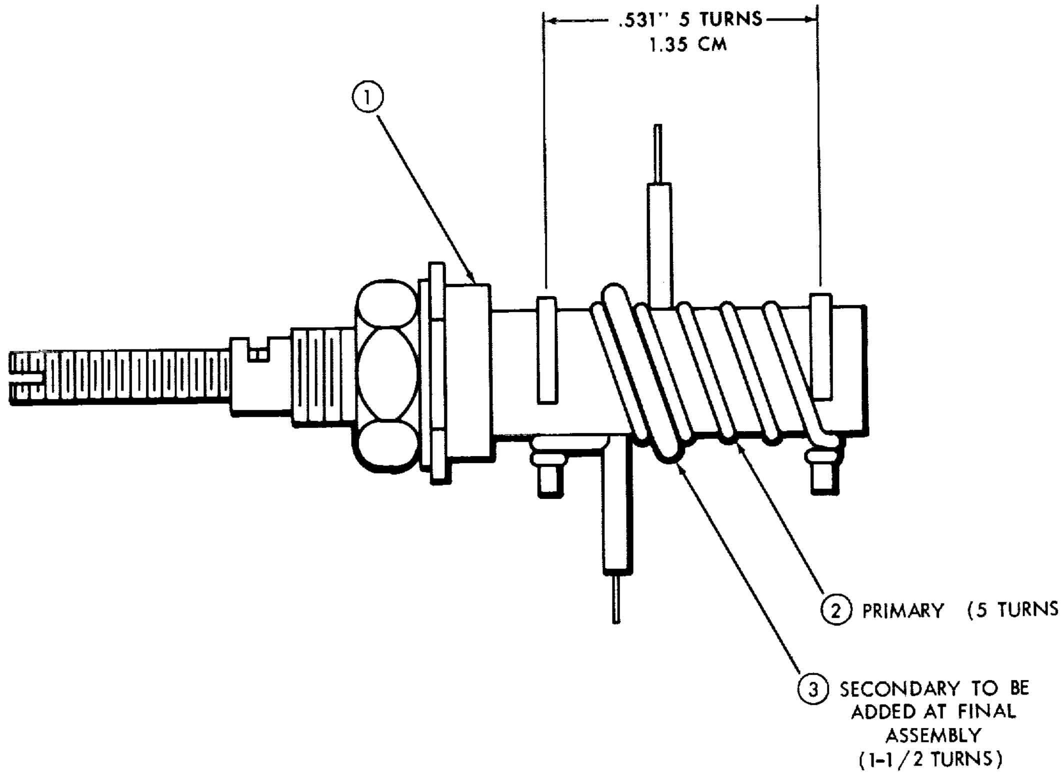
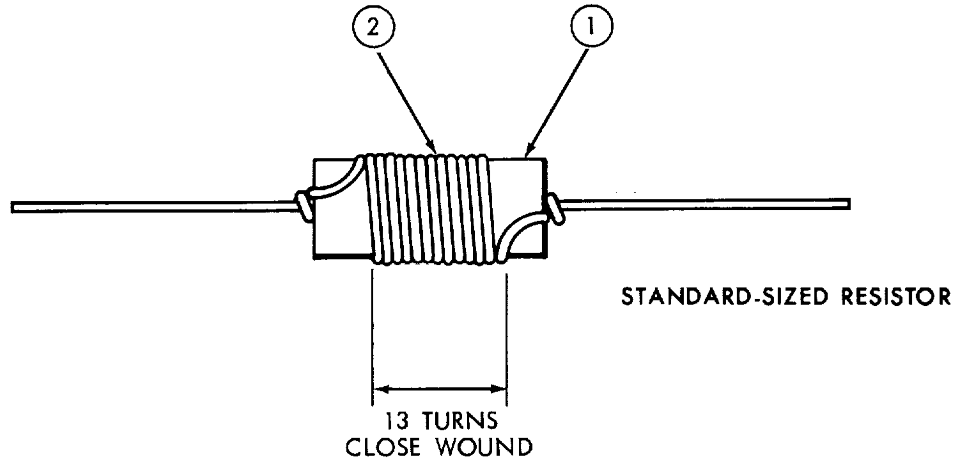


Figure 20.—Antenna preamplifier, version 2, schematic.



	4	SOLDER, SN60/SN63
8530	3	WIRE, SOLID, BELDEN #22, THERMOPLASTIC INSULATION
8020	2	BUS WIRE, BELDEN #20, TINNED COPPER
4500-2	1	COIL FORM, J.W. MILLER
PART NO.	ITEM	DESCRIPTION

Figure 21.—Output transformer T1 for antenna preamplifier, version 2.



	3	SOLDER, SN60/SN63
8065	2	WIRE, SOLID, BELDEN #26 HNC NYCLAD
RN20	1	RESISTOR, FIXED COMPOSITION , 100K, 1/2 WATT
PART NO.	ITEM	DESCRIPTION

Figure 22.—Neutralizing inductor L2 for antenna preamplifier, version 2.

from the receiver through the same coaxial cable that carries the amplified signal. The mounting details and alignment data given for preamplifier version 1 apply to this version also.

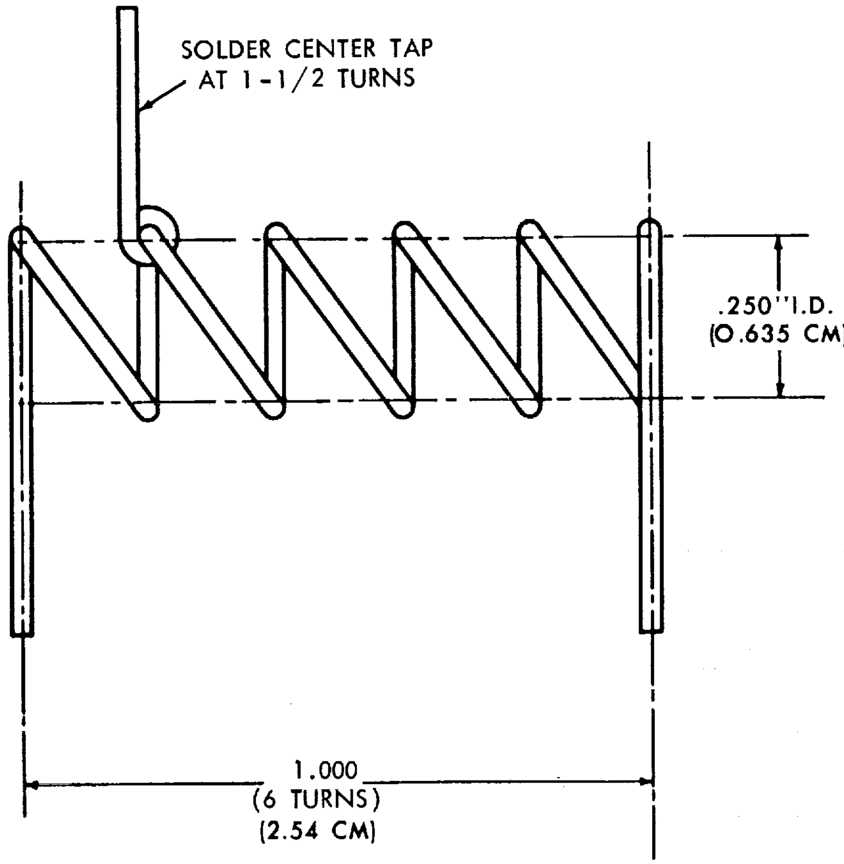
THE FM RECEIVER

PROCUREMENT OR CONSTRUCTION?

The FM receiver is the most critical part of the APT station. It must be relatively noise-free and equipped with automatic frequency control (AFC), automatic gain control (AGC), and a meter to indicate signal strength for tracking purposes.

Whether the receiver is designed for telemetry or is a communication receiver/converter combination, it should:

- Have a 1-microvolt input for 27 db of quieting.
- Have a 50-kHz bandwidth minimum, 80-kHz maximum.
- Be crystal-controlled if possible.



PART NO.	ITEM	DESCRIPTION
	2	SOLDER, SN60/SN63
8019	1	BUS WIRES, BELDEN #18 TINNED COPPER

Figure 23.—Input inductor L1 for antenna preamplifier, version 2.

- Be capable of receiving the following frequencies: 135.6 MHz Weather Facsimile (WEFAX); 136.95 MHz (Nimbus); 137.5 MHz and 137.62 MHz (ESSA).*

The builder may procure his receiver in any of the following ways:

- Most suitable is the use of a standard telemetry receiver—readily available from most surplus equipment dealers. Some receivers may have to be converted to accommodate the necessary frequencies.

*ESSA has proposed that every other APT-equipped satellite use 137.62 MHz to avoid a conflict between two ESSA satellites in operation at the same time.

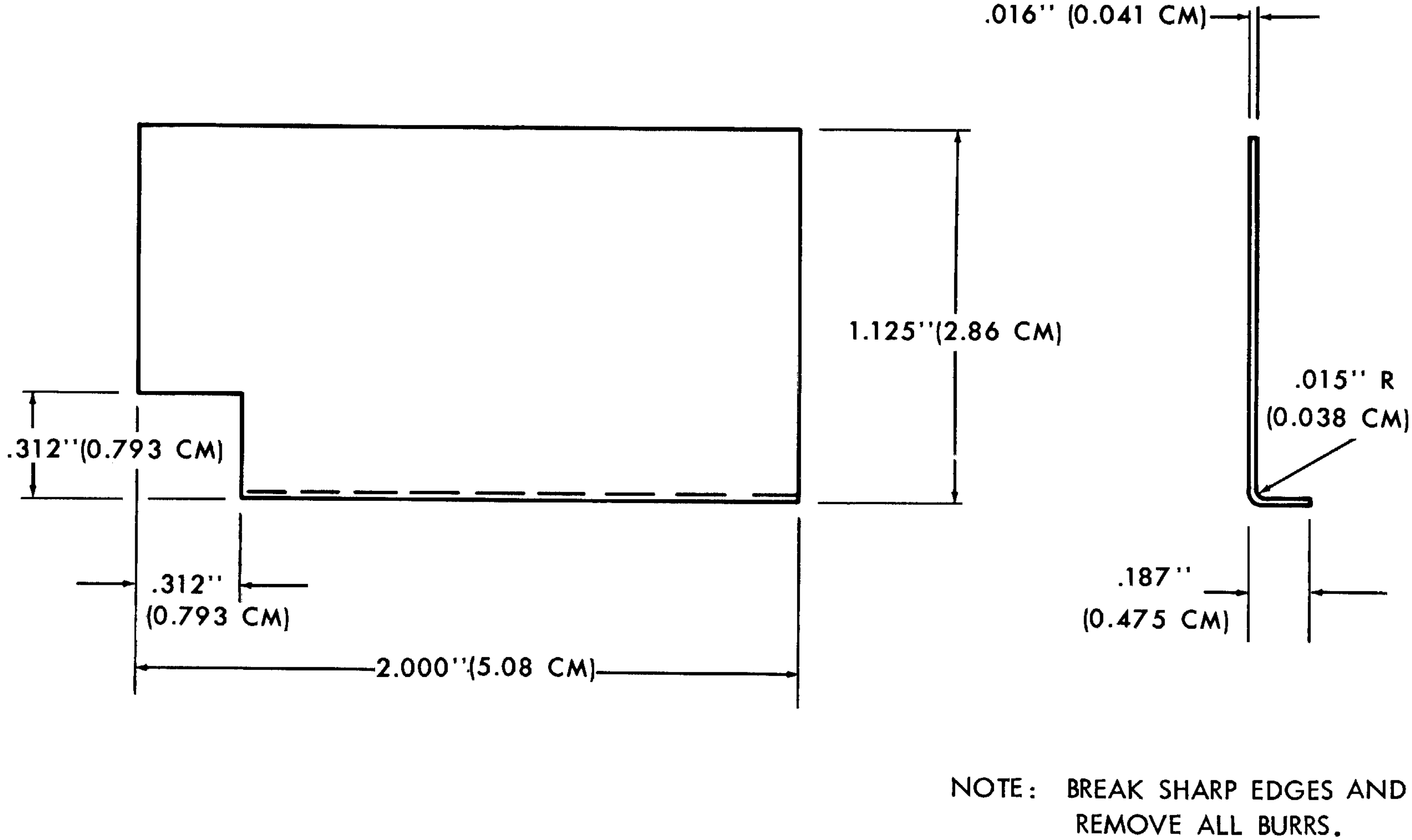


Figure 24.—Shield for antenna preamplifier, version 2.

- Combine a good quality "ham" communications receiver, such as the BC603, and a commercially available frequency converter.* The BC603 is a military designation for an AM-FM receiver; the range of 21 to 25 MHz is satisfactory and is available in this receiver.
- Be sure to specify the four input frequencies mentioned above when ordering the converter and crystals. The frequencies can be converted from the 136-MHz range down to the receiver range. Choose a frequency within the range of the receiver for the converter output. Hardwire the converter output directly to the receiver input. Disconnect the receiver antenna if it is connected and match the impedances to the tracking antenna if they are unmatched. The receiver output must be one volt peak-to-peak for normal operation with the video electronics described under the Facsimile Unit.
- Build the receiver yourself. This is advantageous because you can integrate it into the oscilloscope housing along with the video electronics. Figures 25, 26, 27, 28, and 29 show the schematic and other details needed to build the receiver. The required parts are listed in Appendix A. The crystal specification given by fig. 25 should be used when purchasing the receiver's crystal. The receiver components should be mounted on fiber printed circuit boards, with appropriate holes drilled beneath tuning slugs that have bottom adjustments.

If the receiver is built into the oscilloscope plug-in unit, a plug-in extender must be made. The only mechanical detail of this extender necessary to the functioning of the receiver is that the extender match the oscilloscope's internal connector. The extender permits access to the internal circuits of the receiver. After the receiver is finished, the following alignment procedure should be observed:

FM RECEIVER ALIGNMENT

To align the FM receiver:

(1) Set the frequency of an FM-signal generator to 10.7 MHz to align the IF. Check the frequency with a counter if one is available. If not, refer to suggested procedures in the ARRL or VHF Handbook.

(2) Place the plug-in on the extender and apply power with the POWER ON switch.

(3) Turn the AFC switch to OFF. Connect the output of the FM-signal generator to pin 7 of tube V4.

(4) Connect the oscilloscope to pin 2 of tube V8.

(5) Increase the FM-signal generator output level until a signal is observed on the oscilloscope.

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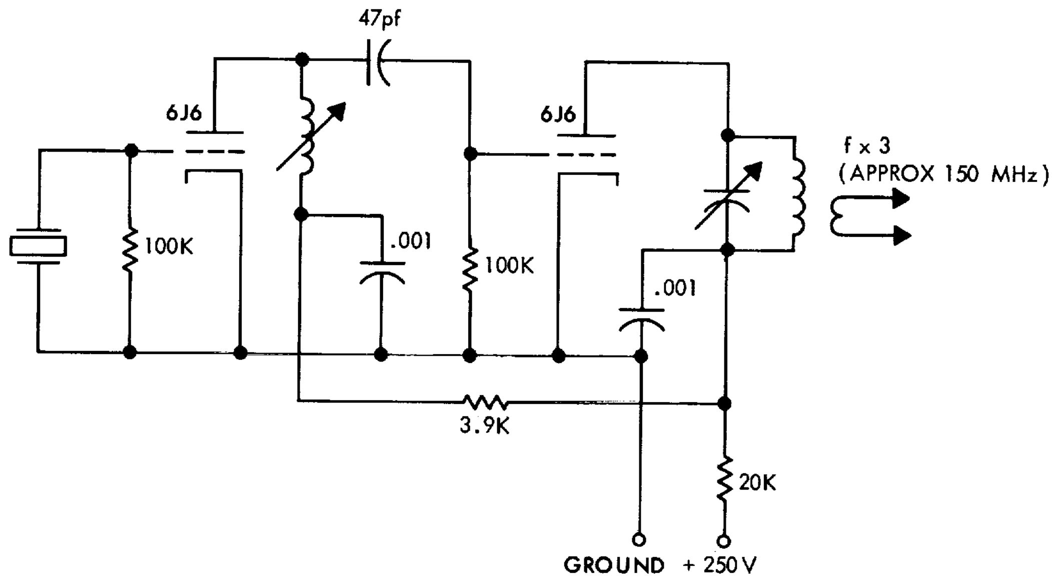
*A suitable converter can be obtained from Ameco Equipment Corporation, Tapetone, and other manufacturers for about $48.00, including the power supply. (Specify input and output frequencies when ordering.)



Crystal to oscillate on overtone

Frequency tolerance to be .005%

Housed in HC6 holder.

Figure 25.—Receiver-crystal circuit schematic.

(6) Using a fiberglass tuning tool, adjust the bottom tuning slug of transformer T8 (reached from the bottom of the plug-in through a hole in the PC board) for maximum amplitude as observed on the oscilloscope. Do not adjust the top tuning slug of T8.

(7) Adjust IF transformer T7 for maximum output amplitude as observed on the oscilloscope. The bottom tuning slug (reached from the bottom side of the plug-in through a hole in the PC board) should be adjusted first, followed by the adjustment of the top tuning slug (through the hole at the top of the IF can).

(8) Repeat step 7 for IF transformer T6.

(9) Repeat step 7 for IF transformer T5.

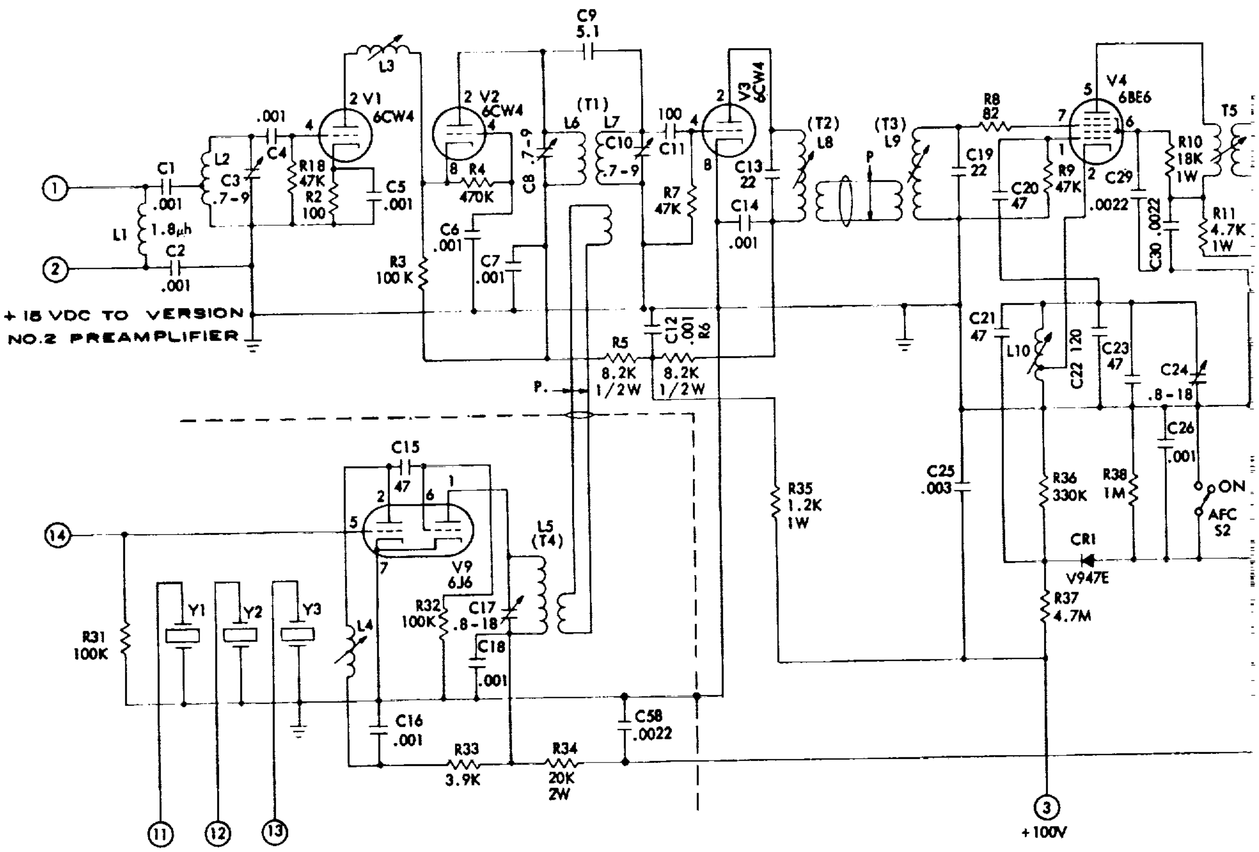
(10) Because of some interaction between stages, repeat steps 6 through 9 if a large adjustment was required for any stage.

(11) Connect the oscilloscope to pin 5 of tube V8.

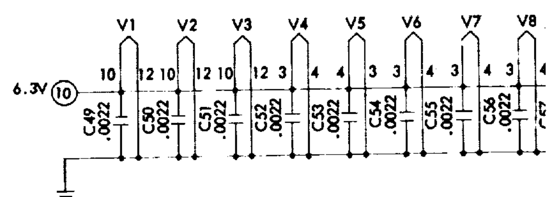
(12) Adjust the top tuning slug of discriminator transformer T8 to zero-volt level at pin 5 of tube V8.

(13) Connect the FM-signal generator to pin 2 of tube V3.

(14) Adjust the FM-signal generator frequency to 17.55 MHz. Check the frequency with a counter.



ALL CAPACITOR VALUES IN MICROFARADS UNLESS OTHERWISE SPECIFIED.



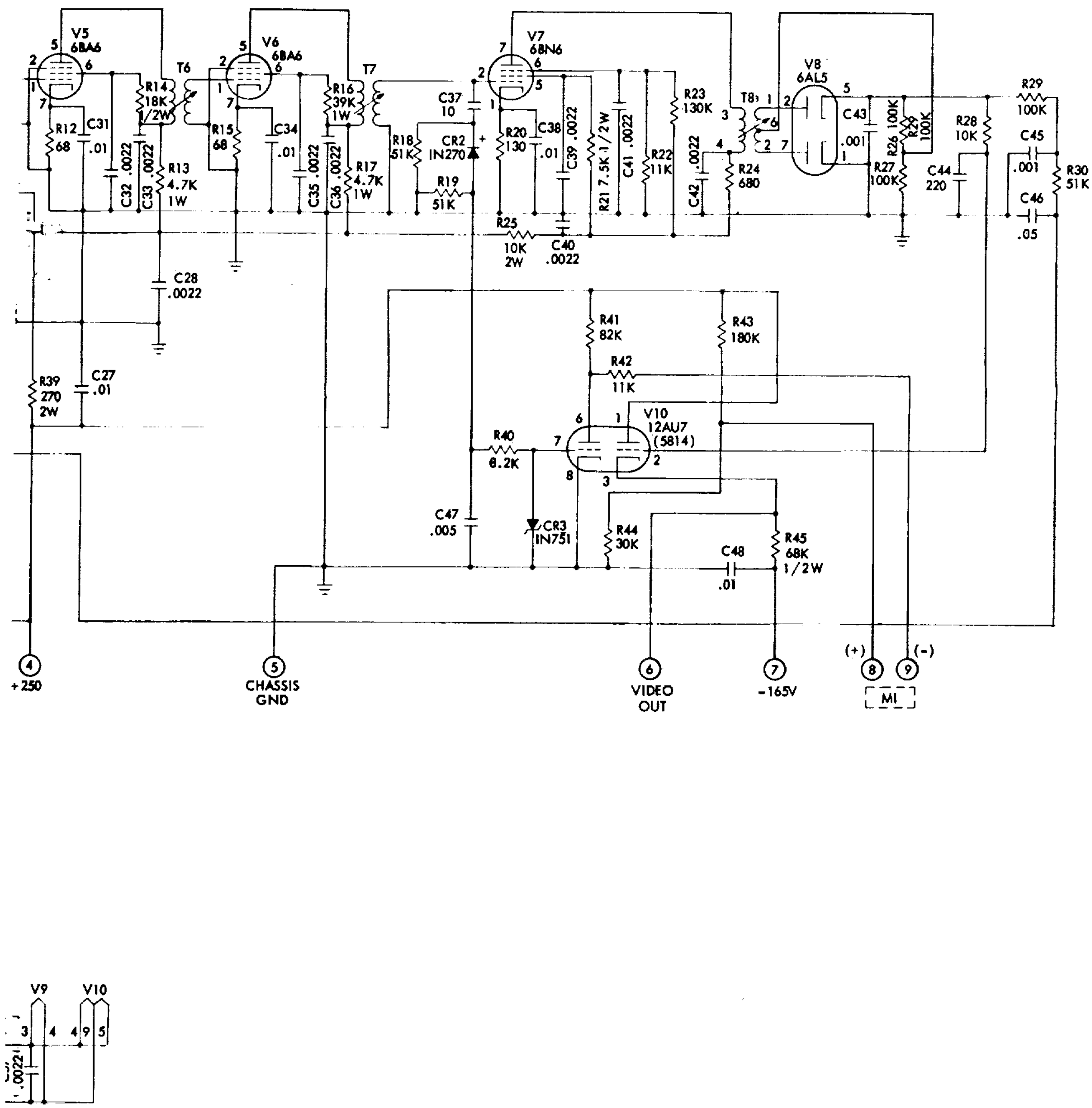
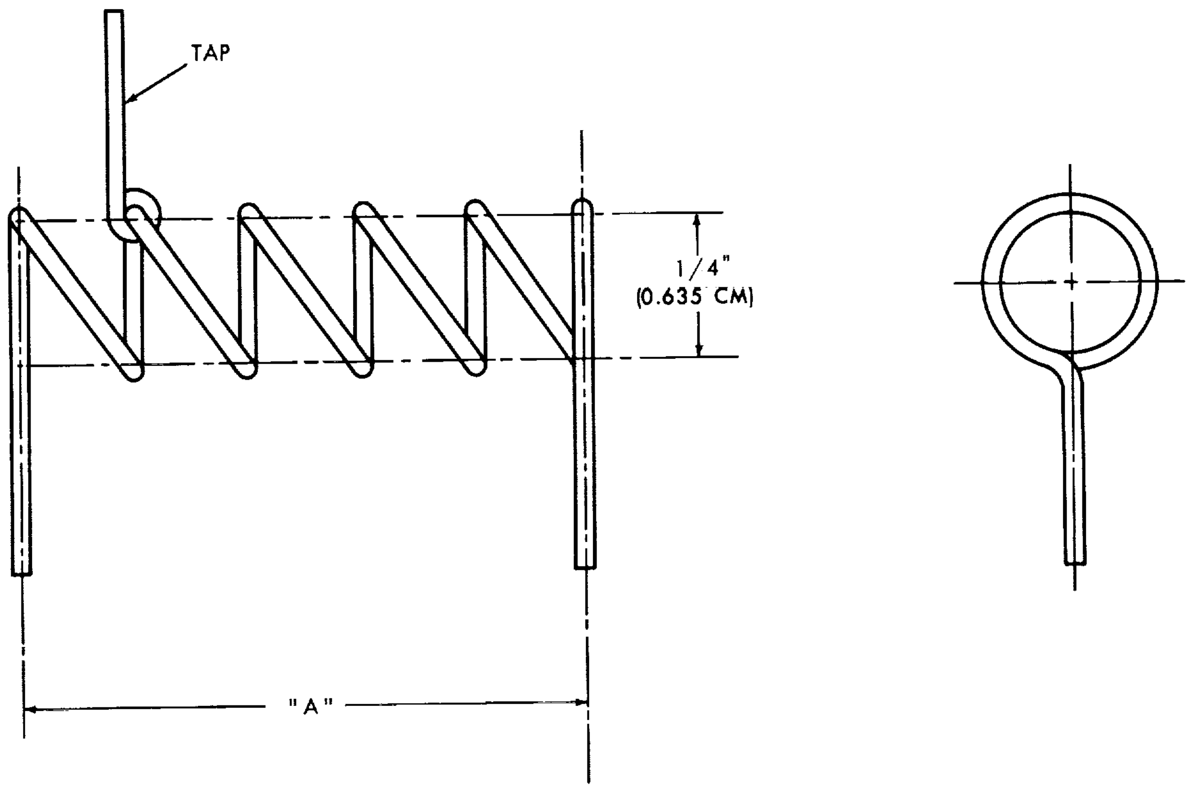


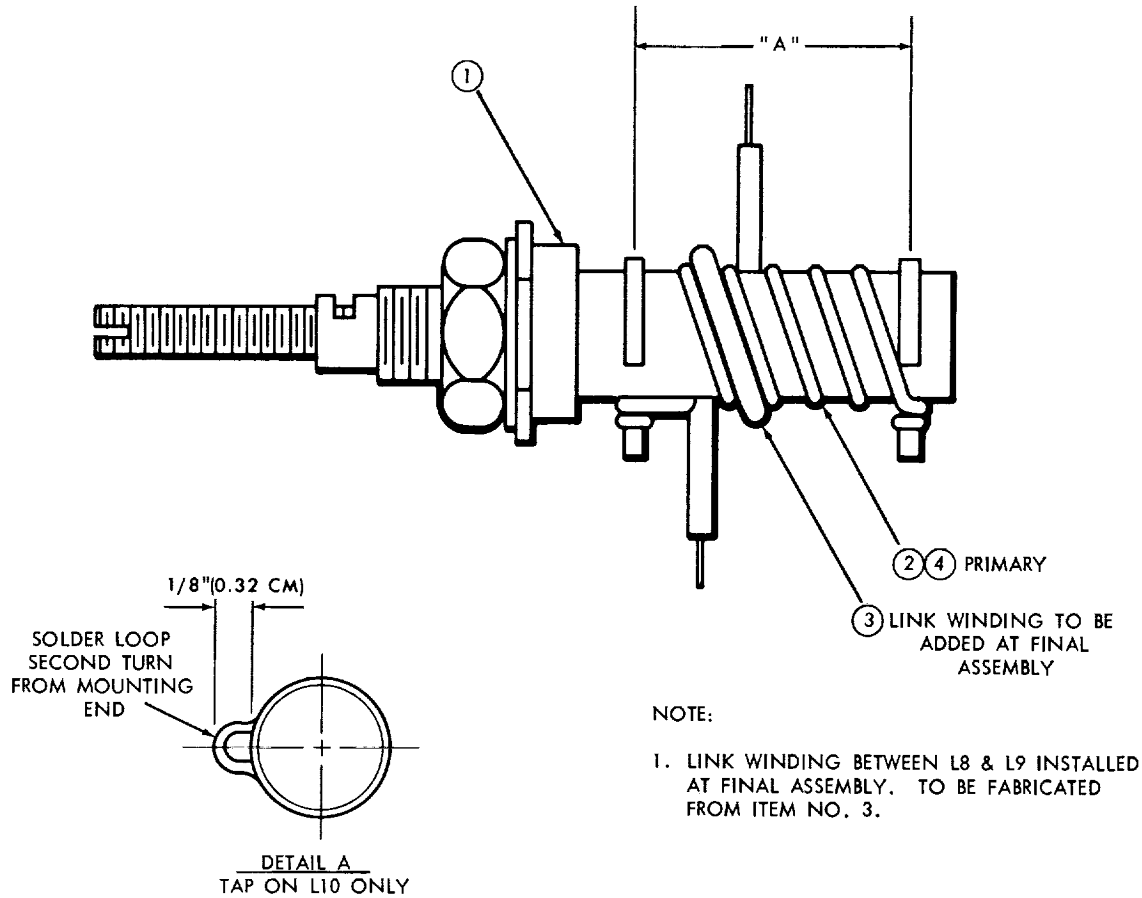
Figure 26. —VHF receiver schematic.



SYMBOL	DIMENSION "A"	NO. OF TURNS	WIRE SIZE	TAP
L2	5/8" (1.59 CM)	4	#18	1 TURN
L5	3/4" (1.90 CM)	6	#18	NONE
L6	3/4" (1.90 CM)	6	#18	NONE
L7	3/4" (1.90 CM)	5	#18	NONE
L1	3/4" (1.90 CM)	6	#18	1 3/4 TURN

	2	SOLDER, SN60/SN63
8019	1	BUS WIRE, BELDEN #18 TINNED COPPER
PART NO.	ITEM	DESCRIPTION

Figure 27.—Inductors L1, L2, L5, L6, and L7 for VHF receiver.



NOTE:

1. LINK WINDING BETWEEN L8 & L9 INSTALLED AT FINAL ASSEMBLY. TO BE FABRICATED FROM ITEM NO. 3.

SYMBOL	DIMENSION "A"	NO. OF TURNS	WIRE SIZE	TAP	LINK WINDING
L4	CLOSE WOUND	9	#26	NONE	NONE
L8	CLOSE WOUND	25	#26	NONE	2 TURNS
L9	CLOSE WOUND	25	#26	NONE	2 TURNS
L10	1/2" (1.27 CM)	6	#18	2 TURNS	NONE

AR		5	SOLDER, SN60/SN63	
AR	8065	4	WIRE, SOLID, BELDEN #26, HNC NYLCLAD	
AR	8035	3	WIRE, SOLID, BELDEN #22, THERMOPLASTIC INSULATION	
AR	8019	2	BUS WIRE, BELDEN #18, TINNED COPPER	
1	4500-2	1	COIL FORM, J. W. MILLER	
REQD	PART NO.	ITEM	DESCRIPTION	SYM

Figure 28.—Inductors L4, L8, L9, and L10 for VHF receiver.

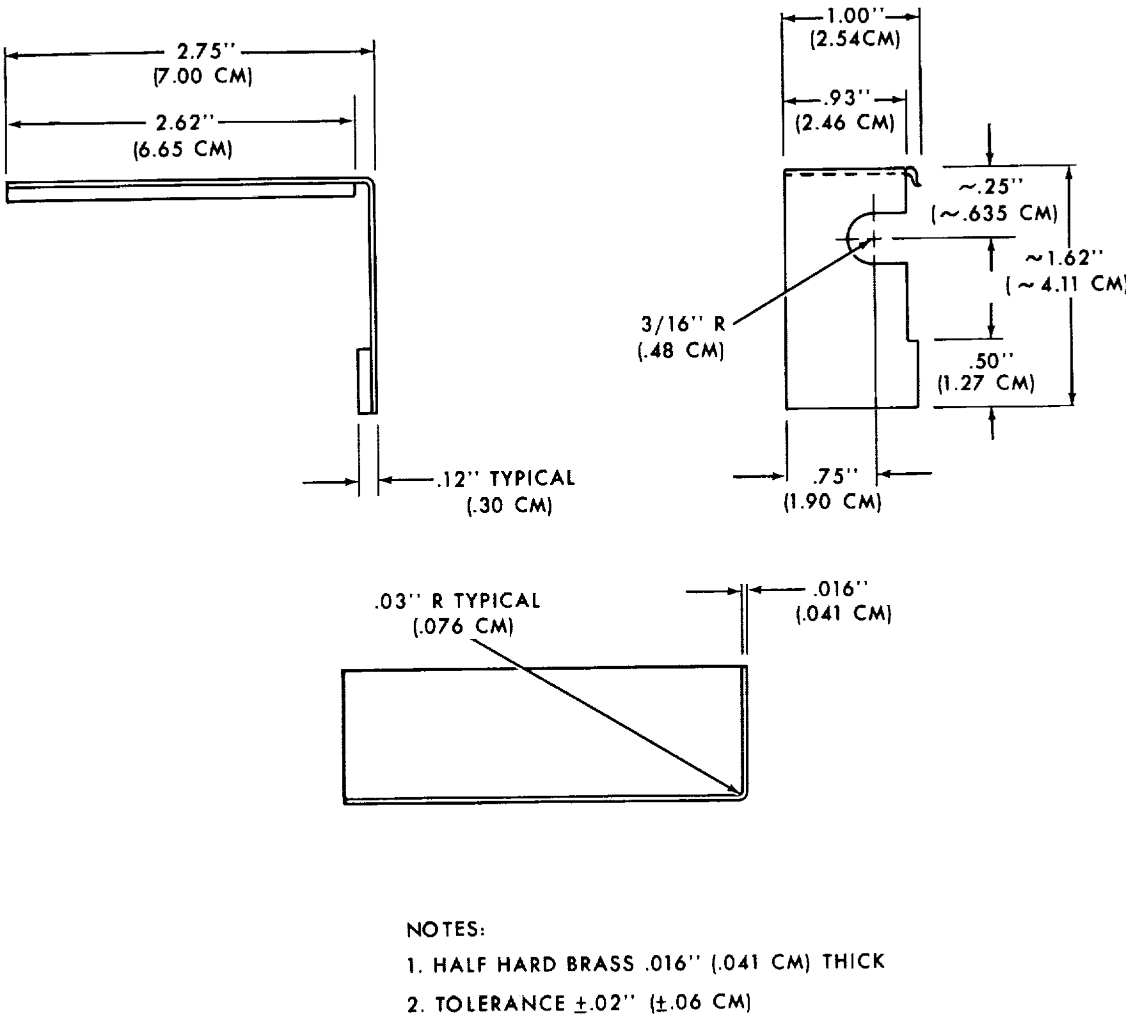


Figure 29.—Shield for VHF receiver.

(15) Observe the signal at pin 7 of tube V8.

(16) Adjust inductor L10 for maximum output. Frequency across L10 should be 28.25 MHz.

(17) Set the CHANNEL switch to B.

(18) Adjust inductor L4 for maximum dc level at the junction of resistors R33 and R37. The level should be from 120 to 160 volts dc. Frequency across L4, which can be checked with a grid-dip meter, should be 51.5 MHz.

(19) Using a grid-dip meter, adjust capacitor C17 for maximum output at 154.5 MHz.

(20) Set the FM-signal generator to 136.95 MHz and 10 kHz deviation. Check the frequency with a frequency counter.

(21) Connect the output of the signal generator to the RF input at the front panel. NOTE: 15 volts dc is supplied through the RF cable to the

antenna preamplifiers; therefore, use capacitor coupling between the signal generator and the RF input.

(22) Connect the oscilloscope to pin 3 of tube V10.
(23) Tune capacitor C10 for maximum output.
(24) Tune capacitor C8 for maximum output.
(25) Tune inductor L3 for maximum output.
(26) Tune capacitor C3 for maximum output.
(27) Set the FM-signal generator to 137.5 MHz and set the CHANNEL selector switch to C. Adjust inductor L9 for maximum output.
(28) Set the FM-signal generator to 135.6 MHz and set the CHANNEL selector switch to A. Adjust inductor L8 for maximum output.
(29) Because of some interaction between stages, steps 21 through 28 should be repeated if a large adjustment was required for any stage.
(30) If the SIGNAL strength meter does not read zero with no signal input, adjustment in voltage divider R43, R44 may be required.
(31) Turn the AFC switch to ON.
(32) Set the FM-signal generator to 136.95 MHz and set the CHANNEL selector switch to B. Observe peak-to-peak amplitude on the CRT when the W. F.-PIC switch is in the W. F. mode. With 10-kHz input deviation applied to the receiver, the signal should be ±0.3 centimeter peak-to-peak in amplitude. Adjustment can be made by changing resistor R95, which is located on the receiver board.

THE FACSIMILE UNIT

The electrical portion of the facsimile unit consists of the video electronics and an oscilloscope display device. The video electronics may be built as a separate unit. If this is done, almost any model oscilloscope may be used. Both the video electronics and the receiver may be built into the same housing as the oscilloscope if an Analab Model M1100 or its equivalent is obtained. This model should be obtained without the plug-in unit and panel markings. Figure 30 shows the finished station when all the electronics are incorporated into the Analab oscilloscope. The oscilloscope must have the following features:

- Flat-face, low-persistency cathode-ray tube (CRT) (such as P11 phosphor), 5 inches (approx. 12 cm) in diameter, with less than 0.005 inch (0.012 cm) spot size for 800-line resolution. (Increased spot size creates slight degradation.)
- X and Y (horizontal and vertical) amplifiers.
- Z-axis input.
- A mounting ring (bezel) to connect "scope" camera.

Figure 31 shows the location of all the controls on the plug-in. The front panel should be made of heavy gauge aluminum for rigidity. Measure the internal space for the plug-in so that the connector already in the oscilloscope may be used.

The last steps are: (1) wiring the video electronics, (2) properly connecting this unit to the oscilloscope, and (3) mounting a scope camera on the CRT. (The

Figure 30.—Assembled APT station.

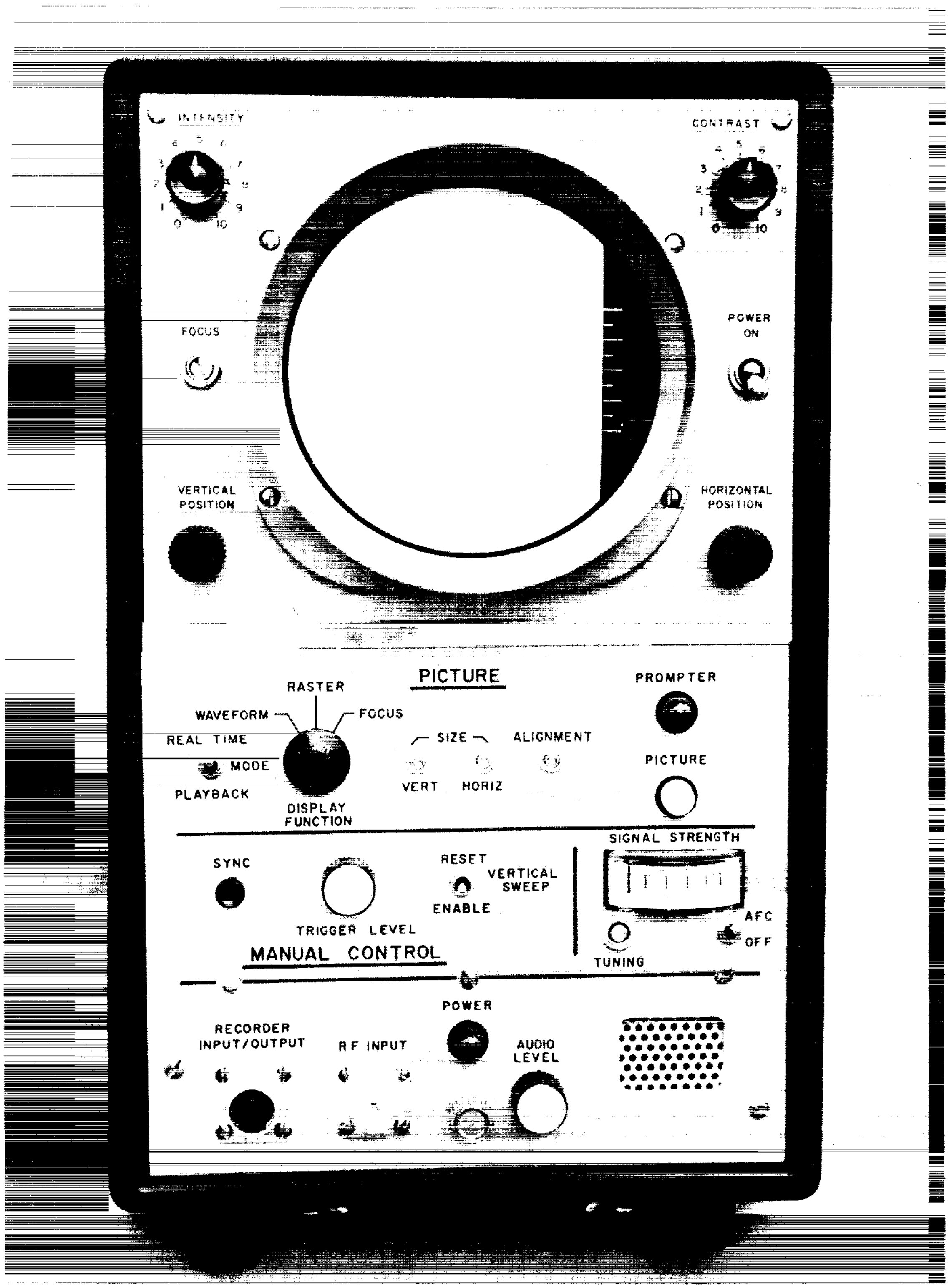


Figure 31.—APT station controls.

video electronics schematic shown in fig. 32.) The necessary parts for the video electronics are listed in Appendix B. A thin metal plate must be constructed for the face of the CRT, and calibrated in centimeters. The video output from the tape recorder (in playback) or receiver (in real time) must be adjusted to 2 cm peak-to-peak; this corresponds to the 800-millivolt output of the amplifier and assures an adequate signal to the Z-axis.

All integrated circuits are of the Fairchild epoxy type.* Semiconductors are from Texas Instruments.* The operational amplifier used (A1 in Fig. 32) is a George Philbrick solid-state P65AU.* The frequency standard is a 2400-cycle tuning fork. The connector shown in Fig. 32 (J2) is the type used in the model 1100 Analab oscilloscope and must be changed if another oscilloscope is used.* Also, the receiver output must be matched to the 10K input impedance of this unit.

THE TAPE RECORDER

Many articles have been written about APT; in some of these the author, seeking ways to reduce the price of APT, suggests that the tape recorder is not essential. However, if any malfunction occurs in the facsimile or the camera, the picture will be lost if it is not recorded on tape. A good quality stereo recorder with one channel for video and the other for recording the sync signal is needed. The facsimile must be triggered by the sync signal in playback because of wow and flutter in the recorder. The tape-recorder requirements are:

- Must record and play back at 7-1/2 ips (approx. 19.5 cm/sec).
- Record and playback levels must have amplitude stability. Any change in output will affect the picture.
- Must be capable of recording 2400 Hz (the video carrier).
- Must be stereo for 2-channel recording.

A tape footage counter is helpful for picture-start reference.

THE CAMERA

The scope camera should have a 4 in. × 5 in. Polaroid back. Type 52 film can be used for normal prints, type 55 for negatives. Be sure to focus the electron beam and the camera to their optimum. The picture size on the film should be adjusted to 3.5 in. × 3.5 in. (approx. 9 × 9 cm).

The video electronics (fig. 32) should be fabricated on a vector-type breadboard and "rigged" up to the scope for troubleshooting. Once operation is established, the breadboard can be incorporated on the plug-in. The video-detecting circuit (fig. 33) can be built into the oscilloscope mainframe.

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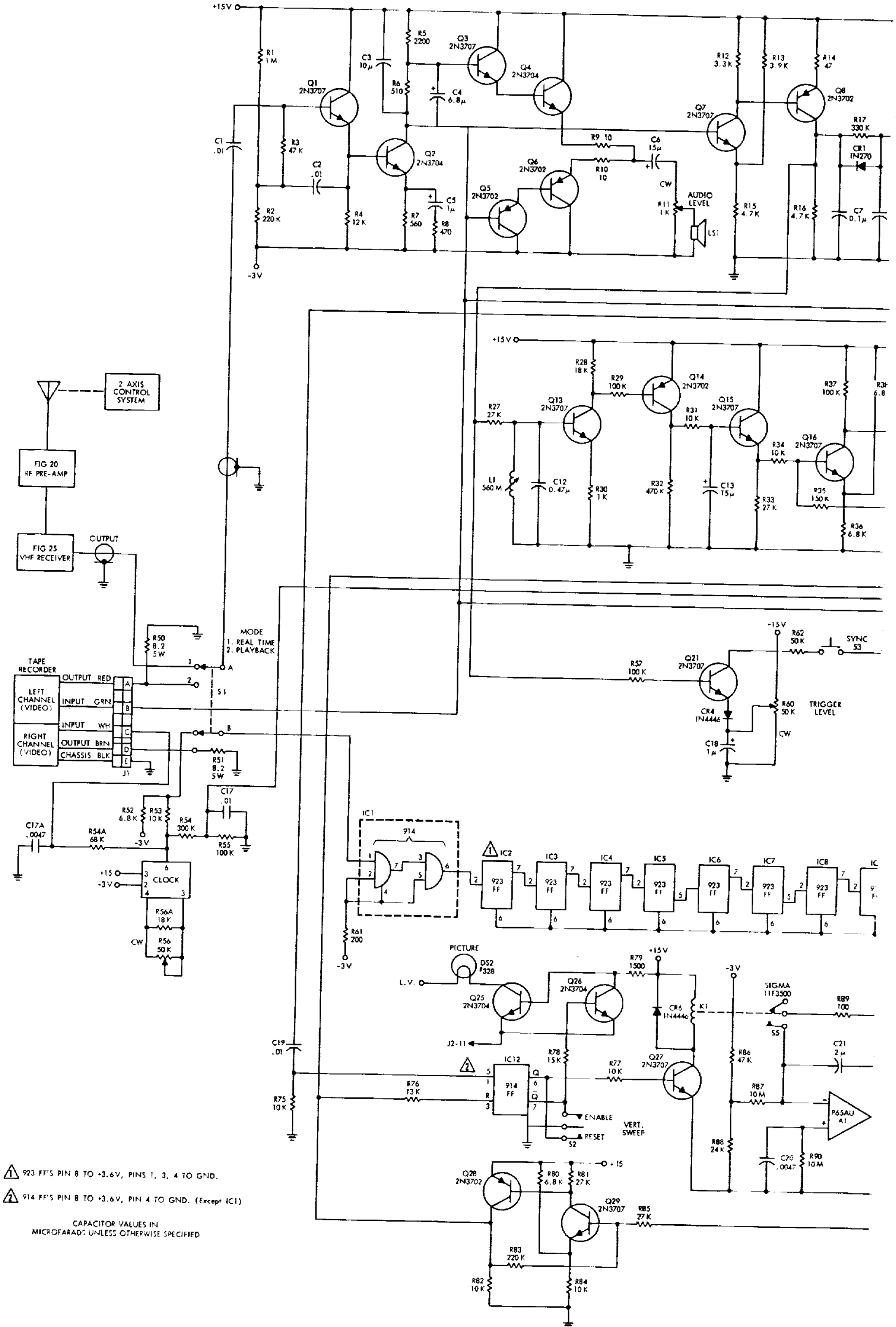
*Other equivalent brands can be used.



1 923 FF'S PIN 8 TO +3.6V, PINS 1, 3, 4 TO GND.

2 914 FF'S PIN 8 TO +3.6V, PIN 4 TO GND. (Except IC1)

CAPACITOR VALUES IN MICROFARADS UNLESS OTHERWISE SPECIFIED

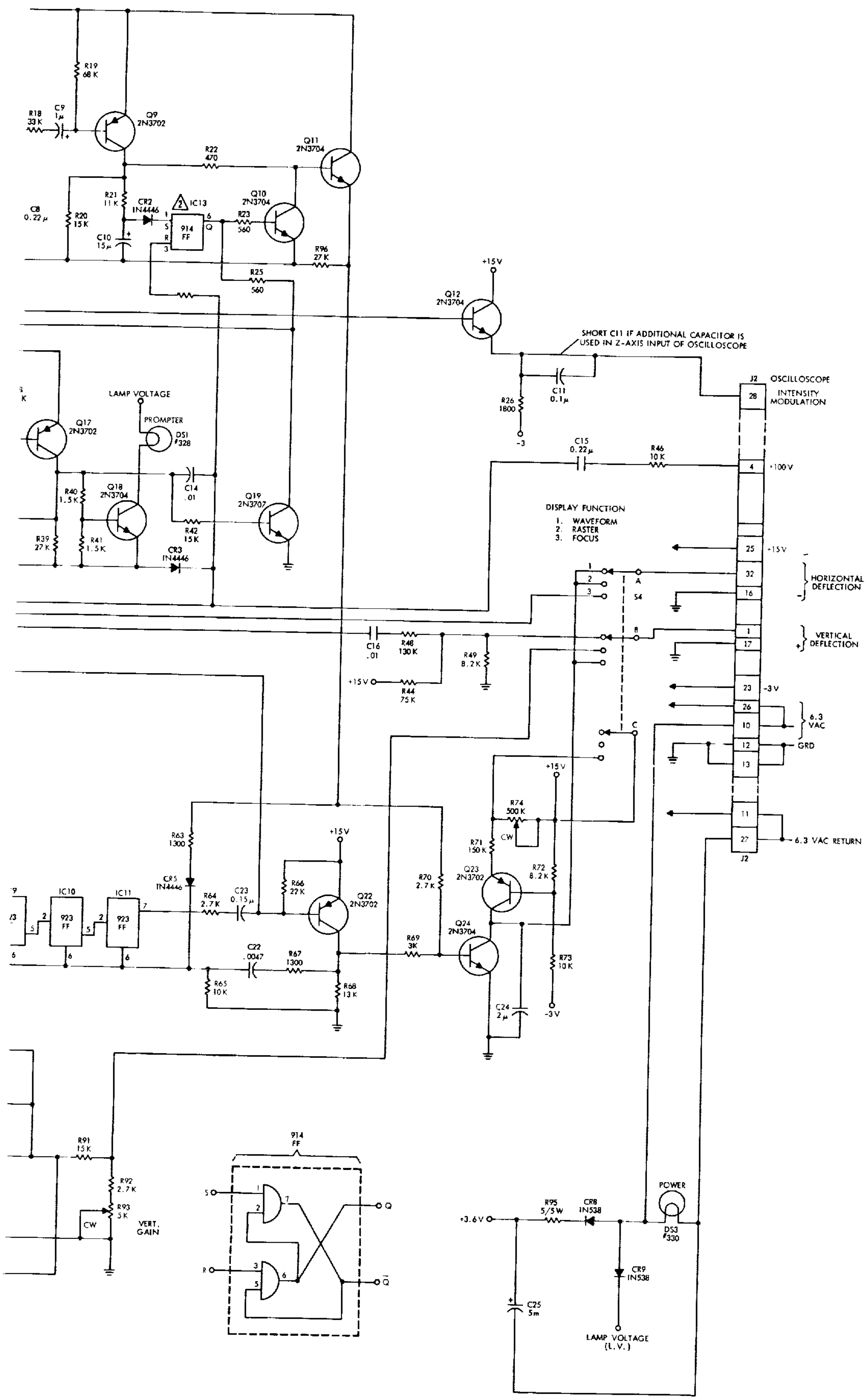


Figure 32. —Video electronics schematic.

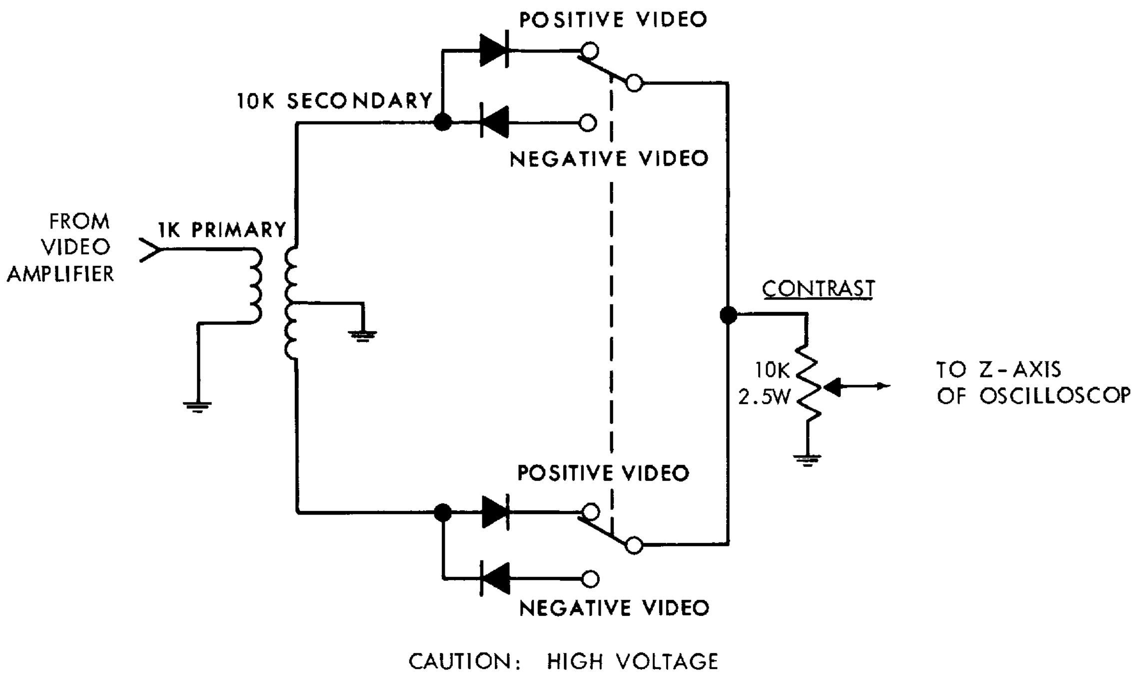


Figure 33. —Video detecting and matching circuit schematic.

CHAPTER 4

Operation Of The Overall System

SYSTEM OPERATION

Figure 34 is a block diagram of the APT station. All system-level discussion is relative to this diagram.

The picture is created a line at a time on the cathode-ray tube (similar to conventional television but at the sweep rates in the satellite camera). The resulting raster is photographed on Polaroid film, which provides a processed photograph about 15 seconds after the end of each picture transmission or about 3.5 minutes after actual exposure by the satellite camera.

Vertical and horizontal sweep generators create the raster, the vertical generator providing a 200-second sweep and the horizontal generator providing a repetitive 250-millisecond sweep. The internal clock and binary dividers control the rate of the horizontal sweep. After the automatic circuitry performs initial synchronization, the horizontal sweep is controlled by the clock (either the actual frequency standard during real-time operation, or the recorded frequency standard signal during playback).

Vertical sweep, produced by an operational integrator containing an operational amplifier, is initiated by the combined control of the 300-Hz detector and the automatic synchronization circuit.

Automatic synchronization occurs during the 5-second period of the video signal just before picture transmission. The synchronization pulse generator is enabled by the 300-Hz detector, then self-disabled after synchronization pulse generation to prevent disruption of the synchronization timing during picture transmission.

The receiver-display unit is capable of either real-time or playback modes of operation. In the unit, the modulated raster is presented for picture photography, the video waveform is presented for calibration and observation, and a focusing waveform may be displayed to facilitate optimum line focusing.

During real-time and playback operation, the adjustment of the output level of the tape recorder or receiver to calibrate the amplitude of the video signal is made by observing the video waveform on the WAVEFORM display function.

The tape-recorder used in this system is a good quality, home-type stereo recorder. One channel contains the video signal and the other contains the clock

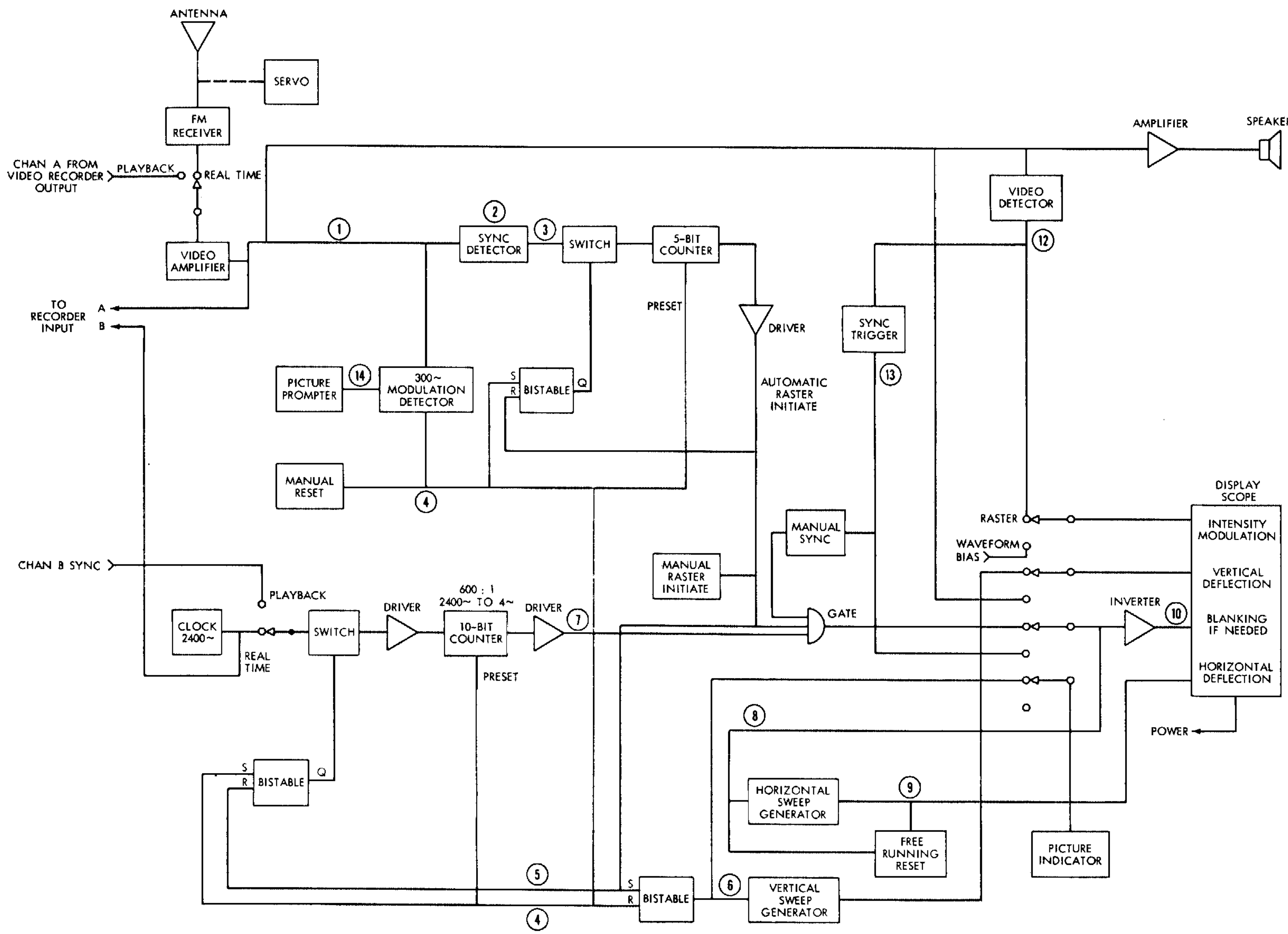


Figure 34.—APT station electronics, block diagram.

signal for accurate picture synchronization. The unit includes a digital display to facilitate location of individual picture information. Operation is simple, as described in the recorder manual. The unit interconnects with the receiver/display unit by the tape-recorder interconnect cable.

The oscilloscope camera shown in fig. 30 is a Fairchild Model 453-A-2.* It rapidly converts from 3.25- by 4.25-inch pack-back to 4- by 5-inch single-sheet operation. The unit's swing-away mount allows easy access to the CRT face and calibration plate. The binocular viewing port permits observation of the CRT display, even during film exposure.

Accessories for the system include photographic film, magnetic tape, and signal and control cables.

CONTROL PANEL FEATURES

- Control Unit (Plug-in).
- MODE switch: selects the video and synchronization signal sources. In the real-time mode, the video signal is received from the FM receiver during actual satellite transmission and synchronization is maintained by the internal frequency standard. In the playback mode, the video signal is received from the tape-recorder video channel, and synchronization is maintained by the recorded clock signal.
- DISPLAY FUNCTION switch: selects the display presented on the CRT phosphor as follows:
  - WAVEFORM: displays the video waveform of successive picture lines, enabling observation of the video signal and amplitude calibration during playback operation.
  - RASTER: displays the modulated raster for picture photography.
  - FOCUS: displays the 2400-Hz clock signal swept vertically at four expanded sweeps per second to enable optimum focusing.
- SIZE CONTROLS
  - VERT: provides adjustment of vertical raster size.
  - HORIZ: provides adjustment of horizontal raster size.
- ALIGNMENT CONTROL: permits adjustment of the frequency of the internal frequency standard, thus controlling any skewing of the picture during scan.
- TRIGGER LEVEL control: sets the level at which the manual synchronization circuit triggers from the video waveform.
- SYNC pushbutton: enables the manual sync trigger circuit.
- VERTICAL SWEEP switch: provides manual reset or initiation of the vertical sweep (automatic during normal operation).
- Tuning control: if the internal receiver was built, this provides optimum tuning of the FM receiver to the satellite RF-transmission frequency.

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*Other equivalent brands can be used.

- AFC Switch: provides enabling or defeat of the automatic frequency control, greatly reducing the effects of internal-receiver local-oscillator drift.
- AUDIO LEVEL control: permits adjustment of the video signal level of audio readout.
- PROMPTER indicator: lights upon the receipt of 300-Hz modulation of the video carrier, indicating the end of the previous picture and prompting the operator for the subsequent picture.
- PICTURE indicator: lights about one second before commencement of picture information, indicating the time for the camera shutter to be opened.
- SIGNAL STRENGTH meter: indicates the relative level of the RF signal received by the antenna (internal receiver).
- POWER light: lights when the power switch is ON and power is applied to the receiver/display unit.
- RECORDER INPUT/OUTPUT connector: provides input and output video and clock signals to and from the tape recorder.
- RF INPUT connector: accepts the RF signal from the RF interconnect cable attached to the RF preamplifier (internal receiver).

Some display unit features are:

- INTENSITY control: permits adjustment of the picture-intensity level.
- CONTRAST control: permits adjustment of the picture contrast.
- FOCUS control: permits adjustment of the focus of the CRT electron beam.
- POWER switch: applies the input power to the unit.
- VERTICAL POSITION control: permits adjustment of the vertical position of the CRT spot.
- HORIZONTAL POSITION control: permits adjustment of the horizontal position of the CRT spot.

The black calibration plate provides amplitude increments for calibration in the "playback" mode.

THE VHF RECEIVER

The operation of the VHF receiver is described stage-by-stage in relation to the receiver schematic, fig. 26. The received RF signal is amplified by a cascade amplifier, V1 and V2, tuned to the 135.6- to 137.5-MHz bandwidth. The amplified RF signal is mixed in transformer T1 with a signal from the first oscillator to produce a 17.55-MHz signal.

The frequency of the first oscillator V9 is determined by one of three crystals selected from the front panel. The choice of crystal depends upon the frequency of the incoming signal, which in turn is dependent on the satellite. The output tank circuit is tuned to the third harmonic of the crystal. This third harmonic is mixed with the incoming RF signal in T1.

The 17.55-MHz signal from T1 is amplified by V3. The amplified signal is then mixed in amplifier V4 with a 28.25-MHz signal from the second oscillator to produce a 10.7-MHz second-IF frequency.

The second oscillator consists of a tuned network whose frequency is determined primarily by a voltage-variable capacitor, CR1. The 10.7-MHz signal is kept frequency-stabilized by feedback from the discriminator output. This automatic frequency control (AFC) action thus keeps the second-IF frequency at the center of the discriminator's bandwidth.

The second-IF signal is amplified by V5, V6, and V7 to produce a 10.7-MHz signal sufficient to drive discriminator V8. The discriminator produces a video output which is applied to cathode follower V10. The video signal both drives the signal level meter and the video electronics.

VIDEO ELECTRONICS

The video electronics consists of the video amplifier, synchronization circuits, a clock, and vertical and horizontal sweep generators. These circuits are shown schematically on fig. 32 and are described in relation to that figure.

The video amplifier, consisting of Q1, Q2, Q3, Q4, Q5, and Q6, receives the video signal from the receiver during real-time mode and from the tape recorder during playback mode. The video signal is voltage-amplified by Q1 and Q2. The resulting signal then drives the speaker through Q3, Q4, Q5, and Q6 and drives the intensity-modulation transformer located in the main frame (fig. 32) through emitter-follower Q12.

The synchronization circuits produce horizontal and vertical reset pulses that precisely align the picture scanned on the cathode-ray tube with the picture transmitted by the spacecraft. The alignment is accomplished during the eight-second inter-picture phasing interval. Vertical sync is achieved during an initial three seconds of 300-Hz modulation of the carrier; horizontal sync is achieved during the following five-second transmission of phasing pulses.

The 300-Hz modulation envelope is detected by a tuned circuit, L1 and C12, resonated at 300 Hz. The detected 300-Hz signal is amplified by Q13 and rectified by Q14. The rectified signal charges C13 positively. Eventually, the positive charge on C13 reaches the threshold voltage of a Schmidt trigger, Q16 and Q17. (Q15 is an emitter - following isolating C13 from the input impedance of Q16.) When the threshold voltage is reached, Q15 produces a transition to +15 volts. This transition causes the following functions to occur:

(1) Turn-on of the PROMPTER lamp through Q18 to alert the operator that the inter-picture phasing period has begun.
(2) Resetting of the horizontal sweep, phasing lockout flip-flop, IC13, through C14.
(3) Turn-off of the PICTURE light by turning off Q25.
(4) Resetting of the vertical sweep generator by resetting flip-flop IC12. (This reset returns the sweep on the cathode-ray tube to the top of the picture.)

Conditions 1, 3, and 4 above are held throughout the five-second phasing-pulse period to the beginning of the next picture. It is during this phasing-pulse period that the horizontal sweep is synchronized.

During the five-second phasing pulse interval, the 250-millisecond blanks are in phase with the 12.5-millisecond tone burst (which begins each horizontal sweep line transmitted during the 200-second picture interval). A reset pulse is developed from each 12.5-millisecond blank. This aligns the tone burst at the left edge of the sweep.

Transistor Q8 amplifies and half-wave rectifies the video signal received from the video amplifier. Capacitor C9 filters the 2400-Hz AM carrier from the video. The network consisting of R19, R20, R21, C10, and CR2 has a characteristic fast pulse-rise time and slow pulse-fall time. Therefore, to turn Q9 on quickly, the 2400-Hz signal rapidly charges C10.

Capacitor C10 remains charged during the first 237.5-millisecond pulse interval. The 12.5-millisecond blank period that follows allows C10 to discharge to the point where Q9 is turned off.

Since the network's rise time response is fast, the negative-going edge of the pulse at the collector of Q9 occurs simultaneously with the beginning of the next 237.5-millisecond pulse. This negative edge is differentiated and applied to Q11 to produce a 7-millisecond reset pulse. This reset pulse performs the following functions:

- Applies a pulse through CR5 to the reset input of the clock countdown flip-flops.
- Sets the IC13 horizontal-sweep phasing-lockout flip-flop. The horizontal-sweep phasing-lockout flip-flop IC13 prevents pulses that would be produced by this horizontal synchronization circuit during the picture interval from resetting the clock countdown flip-flops. This is done by holding the collector of Q9 low with Q11. Q11 is held on with the high-Q output of flip-flop IC13. Another clock countdown reset pulse can occur only after the 300-Hz interpicture interval is received and detected, causing flip-flop IC13 to be reset again.

The clock generates the four-pulse-per-second reset pulses used by the horizontal sweep generator. The frequency source of the clock is a 2400-Hz tuning fork. An internal alignment potentiometer permits adjusting the frequency precisely to 2400 Hz. The tuning-fork output is squared by passing the signal through two gates (IC1). The ten-stage binary counter then divides the 2400-Hz gate output by 600 to obtain the required four pulses per second.

The four pps square wave drives a one-shot circuit to produce a 2-millisecond reset pulse on each negative transition of the binary countdown output square wave.

The pulses produced by the divided clock are coincident with the front edge of the tone burst beginning on each horizontal sweep line. Coincidence is thus created by the countdown reset pulse of the synchronization circuit. This pulse is approximately 7 milliseconds long and occurs at the end of the 12.5-millisecond blank which, when using the 250-millisecond horizontal time reference, is in phase with the tone burst. In order that the tone burst begin at the left edge of the cathode ray tube trace, the binary countdown must be preset by 20 counts (approximately 20 milliseconds).

Amplifier A1 produces a 200-second sawtooth waveform, which is applied to the vertical sweep amplifier. When the 300-Hz interpicture tone is detected by the synchronization circuits, Q27 turns on to close relay K1. Relay K1 discharges the voltage across C21 to zero, driving the output of the operational amplifier to zero. When the phasing interval is completed, K1 opens and the operational amplifier is again permitted to integrate.

A constant current source, a capacitor, and a parallel switch are used to generate the 250-millisecond horizontal sawtooth sweep. The constant current source charges capacitor C24 at a constant rate, producing a linear voltage ramp. The charging current is controlled by the voltage at the base of Q22 and by the value of the emitter-to-collector resistance. The four-pulse-per-second waveform, generated by the clock, is applied to electronic switch Q24, which is placed parallel to C24. Therefore, four times per second the output of C24 is discharged to ground through switch Q24. The 250-millisecond sawtooth waveform is applied to the horizontal-deflection amplifier located within the oscilloscope main frame.

CHAPTER 5

Preparations For Picture Taking

CABLE CONNECTIONS

Before operation, electrical power must be applied to the receiver/display unit, each antenna-positioning control box, and the tape recorder. Interconnecting cables are required as follows:

- Stacking harness from the antenna to the preamplifier input.
- RF cable from the preamplifier output to the receiver/display unit.
- Interconnect cable between the receiver/display unit and the tape recorder.
- Control cables from the antenna positioning system to the control units.

The antenna and antenna-positioning system can be operated by moving the lever switches of the units which control the azimuth and elevation of the antenna. Read the meter scales carefully for proper indication. These units supply power to the drive motors and brake solenoids of the antenna-positioning system.

RECEIVER DISPLAY UNIT PREPARATION

To prepare the receiver display unit for picture taking:

(1) Apply power to the unit with the POWER switch on the display unit front panel. The POWER light should go on. Allow about 15 minutes for warmup.

(2) Set INTENSITY and CONTRAST to 0.

(3) Set the MODE switch to REAL TIME.

(4) Set the DISPLAY FUNCTION switch to RASTER.

(5) Reset the vertical sweep.

(6) Increase the INTENSITY until the horizontal scan line is visible.

(7) Adjust the horizontal and vertical positioning controls so that the line intersects the top corner formed by the circular phosphor edge and the left edge of the calibration graticule (fig. 35).

(8) Now adjust the HORIZONTAL POSITION control counterclockwise until the left end of the scan line touches the edge of the phosphor on the left side.

(9) Next adjust the HORIZONTAL SIZE control so that the right end of the scan line is positioned in the upper corner where the phosphor edge

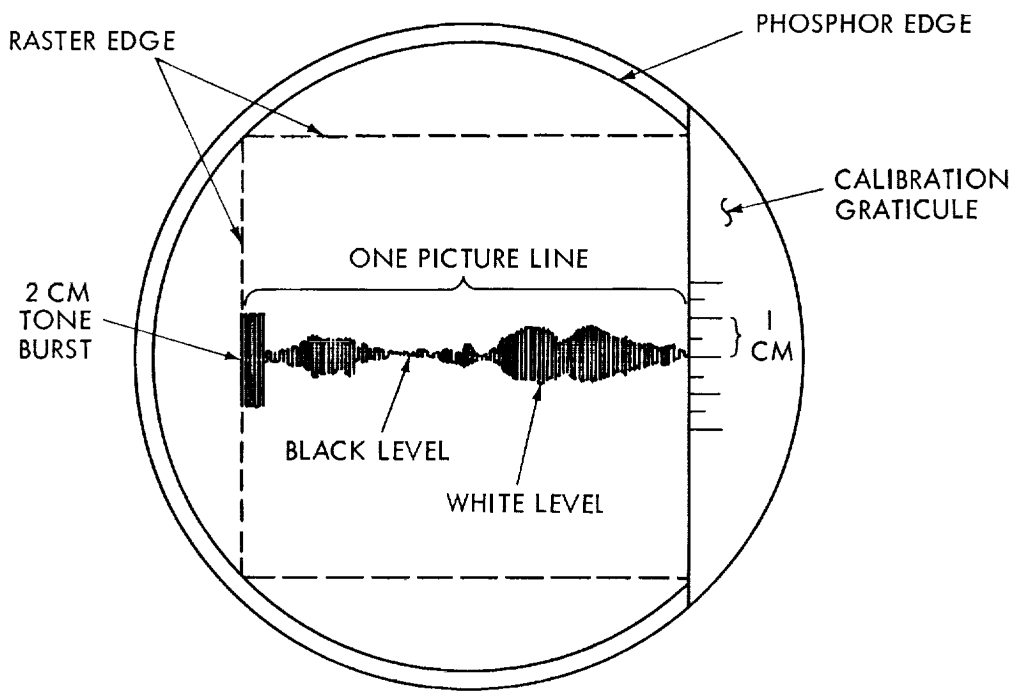

Figure 35.—Oscilloscope showing waveform mode.

meets the calibration graticule. Adjustment of raster size and horizontal size are now complete.

(10) Enable the vertical sweep, and note the time.

(11) After an elapsed time of 200 seconds from the enabling of vertical sweep, adjust the VERTICAL SIZE control so that the right end of the scan line is positioned at the bottom corner formed by the phosphor edge, and at the left edge of the calibration graticule.

(12) Set the DISPLAY FUNCTION switch to FOCUS.

(13) Adjust the intensity for optimum display of the focus signal.

(14) Adjust FOCUS and astigmatism (inside) controls for maximum resolution of the focus signal.

Preliminary picture adjustments are now complete. The position of the scan line, as initially set, should be checked before each period of operation. Focus and vertical raster size can be checked weekly, or less frequently if no adjustment appears necessary.

CAMERA PREPARATION

The camera clamp-ring must be attached to the display unit bezel according to instructions in the camera instruction manual. Next, affix the camera body to the clamp-ring swingaway mount but do not lock it in place.

Two adjustments must now be performed: setting the image size and focusing the image. The display unit scan line may be used to set the image size.

(1) Set the MODE switch to REAL TIME.
(2) Set the DISPLAY FUNCTION switch to RASTER.
(3) Set INTENSITY at 10 and CONTRAST at 0.
(4) Set the VERTICAL SWEEP to RESET. The scan line should be visible at the top of the normal raster area; reposition it if necessary.
(5) Lock the camera into position against the clamp ring.
(6) Set the aperture at f:2.8 and open the shutter.
(7) Open the rear of the Polaroid pack-back, if used, and remove any film pack. Install the focusing adapter.
(8) Referring to the camera manual for the method of adjustment, set up the image size by observing the scan-line image on the focusing plate. Adjust the camera adjustments so that the scan line is placed about 1/8 inch above the bottom edge of the focusing plate.
(9) Open the left-side access door on the camera and, while observing the actual scan line, adjust the vertical position of the scan line, positioning it at the bottom of the normal raster area.
(10) Close the access door and observe the image of the scan line on the focusing plate. It should be visible at the top of the plate. If it is not, adjust the camera-lens position to place the image of the scan line about 1/8 inch down from the top of the focusing plate.
(11) Adjust the vertical position to put the scan line at the top of the normal raster area.
(12) Now switch the DISPLAY FUNCTION switch to FOCUS. Observe the focus waveform on the focusing plate. This may require a magnifying glass and darkened room.
(13) Adjust the position of the camera back to obtain the best focus. The adjustment of the lens position or the camera back may necessitate a readjustment of both to remove observable interaction.
(14) Upon optimum adjustment, lock the camera adjustments. Close the aperture to f:4 and close the shutter. Remove the focusing adapter, install the film pack, and close the camera back.

If a 4 in. × 5 in. back is used as the camera back, preliminary adjustments are similar to those made using the 3.25 in. × 4.25 in. pack-back. Focusing and image size adjustment are accomplished when the 4 in. × 5 in. back is installed and the 4 in. × 5 in. Polaroid adapter has not been installed. After adjustments are complete, the Polaroid adapter may be installed.

TAPE RECORDER PREPARATION

The tape recorder may be used according to its instruction manual, except for the following items:

(1) Attach the interconnect cable according to wiring notations on the "Video Electronics" schematic found in this report.
(2) Approximate normal AUDIO LEVEL and tone settings should be marked on the control panel for both recording and playback.

(3) Good quality magnetic tape (instrumentation grade) should be used for this unit. Lower grade tapes will allow "dropouts" in which several cycles of clock signal may be lost, causing a horizontal shift in the picture.

(4) The tape recorder should be modified so that each channel operates on half a track. The tape may be played in only one direction.

(5) To achieve the disabling of the recorder speaker and to achieve low noise, use the external speaker jacks instead of the preamplifier output in playback. The video electronics is wired for low impedance at the recorder input.

CHAPTER 6

Procedures During Picture Taking

REAL-TIME OPERATION

Before satellite acquisition:

(1) Complete all preliminary operations.

(2) Position the antenna toward ascent "look angle" (Refer to APT User's Guide (ref. 3) for orbital information).

(3) Set the MODE switch to REAL TIME.

(4) Set the AUDIO LEVEL control high enough to pick up receiver noise.

(5) Upon receipt of the satellite signal, adjust TUNING for maximum signal.

(6) Enable the tape recorder in the record mode.

For manual synchronization which is necessary only if the initial picture is required:

(1) Set the DISPLAY FUNCTION switch to WAVEFORM.

(2) Set CONTRAST to 0.

(3) Set INTENSITY to 10.

(4) Observe the video waveform on the CRT phosphor, either by viewing it through the binocular-viewing port or by swinging the camera housing aside. Observe, in the waveform, the full carrier tone bursts. (See fig. 34.)

(5) Adjust the manual sync TRIGGER LEVEL fully CCW.

(6) Depress the SYNC pushbutton and slowly adjust the TRIGGER LEVEL control clockwise until the horizontal sweep is reset by the pulses of the tone bursts. Release the SYNC pushbutton. The tone bursts should now appear at the far left of the sweep opposite the calibration plate. Correct sync is obtained only when manual sync occurs on a full-width tone burst; sync on a half burst may shift one-half of the data code stripe to the opposite side of the picture. This will be corrected upon receipt of picture-sync information at the beginning of the next picture.

(7) Close the binocular viewing port or close and lock the camera housing.

(8) Set the INTENSITY and CONTRAST controls to the desired levels. These levels, which vary with the type of film used, should have been determined through prior use.

(9) Set the DISPLAY FUNCTION switch to RASTER.
(10) Reset and enable the vertical sweep.
(11) Open the camera shutter. The picture is now being photographed.

For automatic synchronization, upon completing the transmission of the first picture:

(1) Set the DISPLAY FUNCTION switch to RASTER.
(2) Set INTENSITY AND CONTRAST as desired. The first complete picture will be indicated by the presence of sync information (a 3-second period of 300-Hz modulation and a 5-second period of partly blanked video carrier). The PROMPTER indicator will light for about 7 seconds and go off, and the PICTURE indicator will then light. Raster scanning should have begun.
(3) When the PICTURE indicator lights, open the camera shutter to expose the film. During reception, it is occasionally necessary to reposition the antenna in order to track the satellite and receive adequate signal level. The antenna position should be updated about every minute, using Nimbus and ESSA look-angle data for the reception locality.
(4) Close the shutter at the end of picture transmission (200 seconds), indicated audibly by the 300-Hz modulation, or visually by the PICTURE light going out.
(5) Remove the exposed film.
(6) When the PICTURE indicator relights, open the shutter to photograph the next picture.
(7) After the recommended development time, separate the Polaroid print from the negative. Immediately coat the print with the print coater supplied with the film.
(8) As the satellite begins to approach the horizon, the signal strength will diminish to a level below the limiting level of the receiver and noise will become audible. The signal-to-noise ratio and the picture quality diminish proportionately. At this point, the satellite pass may be considered complete.
(9) Close the camera shutter, if it is open, and process the picture.
(10) Stop the tape recorder.

If the satellite transmission has been recorded, the picture may be rephotographed by playing back the recording for possible improvement of picture quality by variation of intensity and contrast. Copies may also be produced in this manner.

PLAYBACK OPERATION

(1) Complete all preliminary operations.
(2) Set the MODE switch to PLAYBACK.
(3) Set the DISPLAY FUNCTION switch to WAVEFORM.
(4) Set CONTRAST to 0.
(5) Set INTENSITY to 10.
(6) Install tape to correct the location of recorded data.

(7) Adjust the channel VOLUME AUDIO LEVEL control to provide a 2/cm peak-to-peak signal amplitude for full video carrier which occurs during ESSA tone bursts, Nimbus data code stripe, 300-Hz modulation, or sync waveform. You can adjust the amplitude by comparing it with the calibration plate on which the major divisions are 1-cm increments.

Operation from this point is identical with real-time operation, except for antenna positioning and RF receiver adjustments.

ALTERNATE FACSIMILE UNIT

It may be possible to buy from a surplus outlet a standard facsimile unit such as those used in news agencies or police bureaus. The standard facsimile unit is a mechanical device using gears and clutches in place of electronic sweep cathode-ray tubes.

The video waveform is a standard facsimile format, described earlier, and is adaptable to any 240-rpm mechanical recorder. The described antenna-receiver combination will provide the necessary video signal to operate a 240-rpm recorder without modification. Some facsimilies, however, use a 120-rpm drum speed and will require modification before being used.

Generally, in the following standard facsimile recorders the start and phase procedure is similar but the method of display varies.

- Electrolytic paper: The video is converted from an analog voltage into a "marking current" and applied from a metal bar through the moving paper to a rotating drum. The chemical content of the paper allows a current flow proportional to the incoming video.
  The action of current passing from the metal bar through the paper causes the depositing of iron ions (many: black; a few: white) on the paper, thus reproducing the picture as seen by the spacecraft.
- Photosensitive paper: The video is used to vary a light source, which is usually a gas-filled tube energized to some ionizing potential. The video varies the ionizing potential, causing a proportional change in the intensity of the light tube. The light is optically focused on the photosensitive paper and traverses in a lateral direction to form the 200-second vertical sweep. The paper, in this instance, is formed on a rotating drum which revolves at a 240-rpm rate or four revolutions per second. This constitutes the horizontal frequency of four pulses per second.
  After exposure, the paper is removed from the drum and subjected to a two-chemical developing process. Final prints are available within seconds.
- Negative film: As in the photosensitive paper facsimile, the video, once detected, is applied to a light source. The resultant light beam is focused through a minute aperture and focused once more on an oscillating mirror. The mirror oscillates at four sweeps per second (240 rpm). The image from the mirror is once again focused on a high quality, 70 millimeter, fine grain film. The film slowly traverses in front of the

scanning. A video light beam forms the vertical sweep while an oscillating mirror forms the horizontal sweep.

The preceding types of facsimile recorders are all suited for APT. They may be purchased from a price range of $4,000 to $35,000. Included in the cost of a second-hand unit should be the price of making it operational.

DIRECT READOUT INFRARED (DRIR)

In the near future, weather satellites will have an operational system designed to take nighttime infrared pictures of the earth. This system is similar to and will use the same frequencies as the APT; however, the format has been changed to accommodate the 48-rpm radiometer scan rate. This has necessitated a modification of the APT station design to enable reception. The modification manual should be available by May 1968 from the APT coordinator at GSFC.

Figure 36 is a preliminary block diagram of the DRIR electronics shown in relationship to the present APT electronics. The DRIR electronics will be packaged inside the oscilloscope plug-in. Added to the front panel will be two switches and an indicator light (one switch will select the APT or DRIR mode of operation). The DRIR system takes one continuous unframed picture during nighttime operation, and the unit will provide an indication signal to the operator when the sweeping trace has reached the bottom of the cathode ray tube. After advancing the camera film, the operator initiates the next picture with the vertical reset switch.

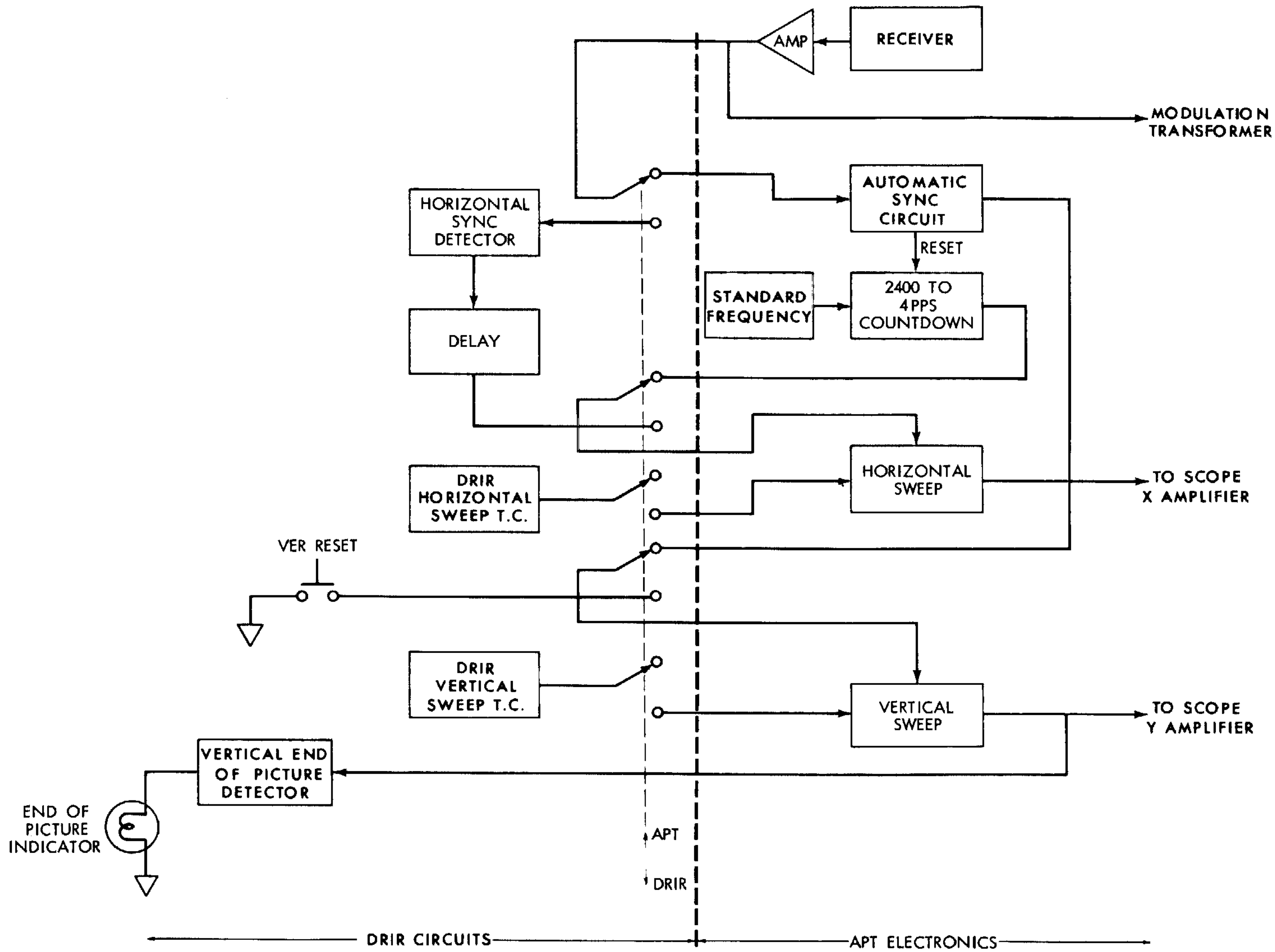

Figure 36.—Proposed DRIR modification, block diagram.

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2. Stampfil, R.A. and Stroud, W.G.: The Automatic Picture-Transmission (APT) TV Camera System for Meteorological Satellites, NASA TN D-1915, 1963.
3. National Weather Satellite Center, Environmental Science Services Administration: The APT User's Guide, Washington, 1965. (Available from the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402, as Document C52-8, $ 1.00)

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Appendix A

VHF Receiver Parts List

Quantity	Part Number	Description	Symbol
		Solder, SN60/SN63	
	8022	Bus wire, #22 tinned copper, Belden*	
35	2010-B	Terminal, Useco*	
4	4500-2	Coil form, ceramic, 1/4" (.635 cm) diameter, J. W. Miller*	L4, L8
		Coil form, ceramic, 1/4" diameter, J. W. Miller*	L9, L10
1	9S2	Shield, tube, 9-pin min., 1-15/16" (4.92 cm) high, Cinch*	
1	7S4	Shield, tube, 7-pin min., 2-1/4" (5.72 cm) high, Cinch*	
4	7S3	Shield, tube, 7-pin min., 1-3/4" (4.45 cm) high, Cinch*	
1	7S2	Shield, tube, 7-pin min., 1-3/8" (3.49 cm) high, Cinch*	
3	04-210-04	Socket, crystal, HC-6 holder, Elco*	
1	9PC-M2	Socket, tube, 9-pin min., P.C., Cinch*	
6	7PC-M2	Socket, tube, 7-pin min., P.C., Cinch*	
3	5NS-2	Socket, tube, Nuvistor, P.C., Cinch*	
3		Crystal units, quarts, as follows: Frequency to be determined by carrier $f(\text{crystal}) = \frac{f(\text{carrier}) + 17.55}{3}$ Channel A = 51.05 MHz (135.6) Channel B = 51.50 MHz (136.95) Channel C = 51.683 MHz (137.50) Channel D = 51.273 MHz (137.62)	
1		Resistor, fixed comp., 270 ohm, 2w 5%	R39
1		Resistor, fixed comp., 20K, 2w 5%	R34
1		Resistor, fixed comp., 10K, 2w 5%	R25
1		Resistor, fixed comp., 1.2K, 1w 5%	R35
1		Resistor, fixed comp., 39K, 1w 5%	R16
3		Resistor, fixed comp., 4.7K, 1w 5%	R11, R3
		Resistor, fixed comp., 4.7K, 1w 5%	R17
2		Resistor, fixed comp., 18K, 1w 5%	R10, R14
1		Resistor, fixed comp., 68K, 1/2w 5%	R45
2		Resistor, fixed comp., 8.2K, 1/2w 5%	R5, R6
1		Resistor, fixed comp., 30K, 1/4w 5%	R44
1		Resistor, fixed comp., 180K, 1/4w 5%	R43
1		Resistor, fixed comp., 82K, 1/4w 5%	R41
1		Resistor, fixed comp., 8.2K, 1/4w 5%	R40
1		Resistor, fixed comp., 1 M., 1/4w 5%	R38
1		Resistor, fixed comp., 4.7 M., 1/4w 5%	R37
1		Resistor, fixed comp., 330K, 1/4w 5%	R36
1		Resistor, fixed comp., 3.9K, 1/4w 5%	R33
1		Resistor, fixed comp., 10K, 1/4w 5%	R28
1		Resistor, fixed comp., 680 ohm, 1/4w 5%	R24
1		Resistor, fixed comp., 130K, 1/4w 5%	R23
2		Resistor, fixed comp., 11K, 1/4w 5%	R22, R42
1		Resistor, fixed comp., 7.5K, 1/4w 5%	R21
1		Resistor, fixed comp., 130 ohm, 1/4w 5%	R20

*Other equivalent brands can be used.

VHF Receiver Parts List — (Continued)

Quantity	Part Number	Description	Symbol
3		Resistor, fixed comp., 51K, 1/4w 5%	R18, R19
		Resistor, fixed comp., 51K, 1/4w 5%	R30
2		Resistor, fixed comp., 68 ohm, 1/4w 5%	R12, R15
1		Resistor, fixed comp., 150 ohm, 1/4w 5%	R8
1		Resistor, fixed comp., 470K, 1/4w 5%	R4
6		Resistor, fixed comp., 100K, 1/4w 5%	R3, R26
		Resistor, fixed comp., 100K, 1/4w 5%	R27, R29
		Resistor, fixed comp., 100K, 1/4w 5%	R31, R32
1		Resistor, fixed comp., 100 ohm, 1/4w 5%	R2
3		Resistor, fixed comp., 47K, 1/4w 5%	R1, R7
		Resistor, fixed comp., 47K, 1/4w 5%	R9
1	12AU7	Tube, electron, RCA*	V10
1	6J6	Tube, electron, RCA*	V9
1	6AL5	Tube, electron, RCA*	V8
1	6BN6	Tube, electron, RCA*	V7
2	6BA6	Tube, electron, RCA*	V5, V6
3	6CW4	Tube, electron, RCA*	V1, V2
		Tube, electron, RCA*	V3
1	1464-PC	Transformer, disctr, 10.7 MHz, J.W. Miller*	T8
3	1463-PC	Transformer, I.F., 10.7 MHz, J.W. Miller*	T5, T6
		Transformer, I.F., 10.7 MHz, J.W. Miller*	T7
1	MST-115D	Switch, miniature toggle, SPDT, Alco*	S2
1		Inductor, per Figure 27	L10
1		Inductor, per Figure 27	L9
1		Inductor, per Figure 27	L8
1		Inductor, per Figure 27	L4
1		Inductor, per Figure 25	L7
1		Inductor, per Figure 25	L6
1		Inductor, per Figure 25	L5
1		Inductor, per Figure 25	L2
1		Inductor, per Figure 25	L1
1	20A337RB1	Inductor, J.W. Miller*	L3
1	IN751	Diode, zener, 5. 1v Motorola*	CR3
1	IN270	Diode, germanium, Sylvania*	CR2
1	V47E/947	Diode, volt. var. cap., 4-7pf/14V, TRW*	CR1
21	DD-222	Capacitor, 0.0022µf/1000v (GMV), Centralab*	C28, C29
		Capacitor, 0.0022µf/1000v (GMV), Centralab*	C30, C32
		Capacitor, 0.0022µf/1000v (GMV), Centralab*	C33, C35
		Capacitor, 0.0022µf/1000v (GMV), Centralab*	C36
		Capacitor, 0.0022µf/1000v (GMV), Centralab*	C39, C42
		Capacitor, 0.0022µf/1000v (GMV), Centralab*	C49-C58
1	DD-502	Capacitor, 0.005µf/1000v (GMV), Centralab*	C47
1	DA-503	Capacitor, 0.05 µf/30v 100-20%, Centralab*	C46
1	DM-221	Capacitor, 220 pf/1000v 10%, Centralab*	C44
1	DM-10-100J	Capacitor, 10 pf 500v 5%, Elemenco*	C37
5	DD-6-103	Capacitor, 0.01µf/600v (GMV), Centralab*	C27
		Capacitor, 0.01µf/600v (GMV), Centralab*	C31
		Capacitor, 0.01µf/600v (GMV), Centralab*	C34
		Capacitor, 0.01µf/600v (GMV), Centralab*	C38
		Capacitor, 0.01µf/600v (GMV), Centralab*	C48
1	DD-302	Capacitor, 0.003µf/1000v (GMV), Centralab*	C25
1	DM-10-121G	Capacitor, 120 pf/500v 2%, Elemenco*	C22
1	VC-4-G	Capacitor, Variable, .8-18.0 pf, J.F.D.*	C24

*Other equivalent brands can be used.

VHF Receiver Parts List — (Concluded)

Quantity	Part Number	Description	Symbol
3	DM-10-470J	Capacitor, 47 pf/500v 5%, Elemenco*	C15, C20
		Capacitor, 47 pf/500v 5%, Elemenco*	C21
2	DC-220K	Capacitor, 22 pf/200v 10%, Nytronics*	C13, C19
1	DM-10-101J	Capacitor, 100 pf/500v 5%, Elemenco*	C11
1	DM-10-050K	Capacitor, 5 pf/500v 5%, Elemenco*	C9
4	VC-1-G	Capacitor, Variable, 0.7-9.0 pf, J.F.D.*	C3, C8
		Capacitor, Variable, 0.7-9.0 pf, J.F.D.*	C10, C17
11	DD-102	Capacitor, 0.001μf/1000v 10%, Centralab*	C2, C5
		Capacitor, 0.001μf/1000v 10%, Centralab*	C6, C7
		Capacitor, 0.001μf/1000v 10%, Centralab*	C12, C14
		Capacitor, 0.001μf/1000v 10%, Centralab*	C16, C18
		Capacitor, 0.001μf/1000v 10%, Centralab*	C26, C43
		Capacitor, 0.001μf/1000v 10%, Nytronics*	C45
2		Capacitor, 0.001μf/100v 10%, Nytronics*	C1, C4
1	DM10---	Capacitor-valve, "TBD," Elemenco*	C23

*Other equivalent brands can be used.

Appendix B

Video Electronics Parts List

Note: This list is subject to revision and should be used only as a guide.

Quantity	Part Number	Description
1	WMF1D22	Capacitor, mylar, 0.0022μf/100V 10%, Cornell-Dubilier*
3	WMF1D47	Capacitor, mylar, 0.0047μf/100V 10%, Cornell-Dubilier*
6	WMF151	Capacitor, mylar, 0.01μf/100V 10%, Cornell-Dubilier*
1	WMF1S47	Capacitor, mylar, 0.047μf/100V 10%, Cornell-Dubilier*
4	MFP1P1	Capacitor, mylar, 0.1μf/100V 10% Cornell-Dubilier*
1	MFP1P22	Capacitor, mylar, 0.22μf/100V 10%, Cornell-Dubilier*
2	MFP2P47	Capacitor, mylar, 0.47μf/100V 10%
3	150D105X0035A2	Capacitor, solid tantalum, 1μf/50V 20%, Sprague*
2	Y146XR-15	Capacitor, solid tantalum, 2μf/50V 20%, Aerovox*
1	150D685X0035B2	Capacitor, solid tantalum, 6.8μf/50V 20%, Sprague*
1	150D156X0020B2	Capacitor, solid tantalum, 15μf/50V 20%, Sprague*
2	MTP226MO15P1A	Capacitor, wet tantalum, 22μf/15V 20%, Mallory*
1	MTP157M020P1C	Capacitor, wet tantalum, 150μf/20V 20%, Mallory*
1	39D508G010HP4	Capacitor, al. electrolytic, 5000μf/10V 20%, Sprague*
1		Resistor, carbon comp., 8.2 ohm, 1/4w 5%
2		Resistor, carbon comp., 10 ohm, 1/4w 5%
1		Resistor, carbon comp., 15 ohm, 1/4w 5%
1		Resistor, carbon comp., 220 ohm, 1/4w 5%
2		Resistor, carbon comp., 560 ohm, 1/4w 5%
3		Resistor, carbon comp., 1K, 1/4w 5%
2		Resistor, carbon comp., 1.2K, 1/4w 5%
2		Resistor, carbon comp., 1.3K, 1/4w 5%
4		Resistor, carbon comp., 1.5K, 1/4w 5%
1		Resistor, carbon comp., 2.2K, 1/4w 5%
1		Resistor, carbon comp., 3K, 1/4w 5%
1		Resistor, carbon comp., 4.7K, 1/4w 5%
3		Resistor, carbon comp., 6.8K, 1/4w 5%
1		Resistor, carbon comp., 7.5K, 1/4w 5%
2		Resistor, carbon comp., 8.2K, 1/4w 5%
1		Resistor, carbon comp., 9.1K, 1/4w 5%
8		Resistor, carbon comp., 10K, 1/4w 5%
1		Resistor, carbon comp., 12K, 1/4w 5%
2		Resistor, carbon comp., 13K, 1/4w 5%
3		Resistor, carbon comp., 15K, 1/4w 5%
3		Resistor, carbon comp., 16K, 1/4w 5%
1		Resistor, carbon comp., 18K, 1/4w 5%
1		Resistor, carbon comp., 20K, 1/4w 5%
1		Resistor, carbon comp., 22K, 1/4w 5%
7		Resistor, carbon comp., 27K, 1/4w 5%
2		Resistor, carbon comp., 47K, 1/4w 5%
1		Resistor, carbon comp., 51K, 1/4w 5%
2		Resistor, carbon comp., 56K, 1/4w 5%
1		Resistor, carbon comp., 62K, 1/4w 5%
1		Resistor, carbon comp., 68K, 1/4w 5%
2		Resistor, carbon comp., 82K, 1/4w 5%
4		Resistor, carbon comp., 100K, 1/4w 5%
1		Resistor, carbon comp., 150K, 1/4w 5%

*Other equivalent brands can be used.

Video Electronics Parts List — (Concluded)

Quantity	Part Number	Description
2		Resistor, carbon comp., 180K, 1/4w 5%
2		Resistor, carbon comp., 220K, 1/4w 5%
1		Resistor, carbon comp., 330K, 1/4w 5%
1		Resistor, carbon comp., 470K, 1/4w 5%
1		Resistor, carbon comp., 1.5 M, 1/4w 5%
2		Resistor, carbon comp., 10 M, 1/4w 5%
1		Resistor, carbon comp., 4.7 ohm, 1w 5%
1		Resistor, carbon comp., 110 ohm, 2w 5%
1	V-4	Potentiometer, 1 turn, 1K, 1w 20%, Mallory*
2	273-1-502M	Potentiometer, 25 turn, 5K, 1/4w 10%, Bourn*
1	273-1-103M	Potentiometer, 25 turn, 10K, 1/4w 10%, Bourn*
1	U-35	Potentiometer, 50K, 1w 20%, Mallory*
1	F1-100K-R1-100K	Potentiometer, 1 turn-dual, 100K, 1/2w 20%, Centralab*
10	2N3702	Transistor, Texas Instrument*
8	2N3704	Transistor, Texas Instrument*
8	2N3707	Transistor, Texas Instrument*
5	IN4446	Diode, General Electric*
2	IN538	Diode, Texas Instrument or General Electric*
1	IN270	Diode, Sylvania*
3	mL91428	Integrated ckt, dual gate, Fairchild*
10	mL92328	Integrated ckt, J-K flip-flop, Fairchild*
1	VIC-10	Inductor, variable, 0.54H
1	FS-32 (Special)	Frequency standard, 2400 Hz, American Time Products*
1	PG65AU	Amplifier, operational, Philbrick*
2	#328	Lamp, mid. flanged T-1-3/4, General Electric*
1	#330	Lamp, mid. flanged T-1-3/4, General Electric*
1	162-843-933-502	Lamp holder, yellow, Dialco*
1	162-843-975-502	Lamp holder, white, Dialco*
1	162-843-931-502	Lamp holder, red, Dialco*
1	Model 13.0-1 Ma.	Meter, Emico*
1	MFG. Type 250	Phone plug, black, Switchcraft*
2	3502	Phone plug, Switchcraft*
1	26-159-32	Connector, Amphenol*
3	50-6007-3314	Connector, insert polarization, Elco*
1	22A062100	Speaker, 2-1/2" (5 cm), 100 ohm, Quam*
8	K-700G	Knob, aluminum instrument knobs
1	K-500G	Knob, aluminum instrument knobs
1	50-2-1G	Knob, Raytheon*
2	115-253	Flexible shaft, E.F. Johnson*
1	Allied 47D4096	Bearing, H.H. Smith
5 ft	8445	Tape recorder cable, Belden*

*Other equivalent brands can be used.

NASA-Langley, 1968